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SIR HUMPHRY DAVY, Bart.

THE
COLLECTED WORKS
OF
SIR HUMPHRY DAVY, BART.

LL.D. F.R.S.

FOREIGN ASSOCIATE OF THE INSTITUTE OF FRANCE, ETC.

EDITED BY HIS BROTHER,

JOHN DAVY, M.D. F.R.S.

VOL. II.

EARLY MISCELLANEOUS PAPERS.

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EARLY

MISCELLANEOUS PAPERS,

FROM 1799 TO 1805.

WITH

AN INTRODUCTORY LECTURE,

AND

OUTLINES OF LECTURES ON CHEMISTRY,

DELIVERED IN 1802, AND 1804.

BY SIR HUMPHRY DAVY, BART.

LONDON:
SMITH, ELDER AND CO. CORNHILL.
1839.

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ADVERTISEMENT.

This Volume contains the whole of the Author's Miscellaneous Papers, from 1799 to 1805; and also an early Introductory Lecture on Chemistry, with Outlines of Two Courses of Lectures on Chemistry and on Chemical Philosophy.

It is mainly interesting on two accounts: one, as illustrating the progress of Chemical Discovery, and more especially of Voltaic Electricity; the other, as displaying the progress of the Author's own mind, and the formation of his philosophical character.

In the arrangement of the papers, attention has been paid to time, in relation to the order of their first appearance; from which no deviation has been permitted, excepting in instances in which it appeared advisable on account of the similar nature of the subjects and a natural connexion.

The few notes introduced by the Editor are distinguishable by being placed within brackets.

JOHN DAVY.

Fort Pitt, Chatham,
August 10*th*, 1839.

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AN ESSAY

ON

HEAT, LIGHT,

AND

THE COMBINATIONS OF LIGHT.

[This and the following Essay, the Author's first contribution to science, were published early in 1799.* They were commenced at Penzance, shortly after he had entered on the study of Chemistry; and were finished at Clifton, twenty months later.

Less than two years after, namely in December, 1800, referring to these productions, he designates them, "my infant chemical speculations"; † and, considering them chiefly in the light of mere speculations, he appears then to have greatly under-rated them, and to have formed an opinion of them himself far more unfavourable than they deserved as a whole, or than posterity, it is probable, will acknowledge to be correct.

The following estimate of them was made at the time, by a very able judge, and candid critic, the distinguished and venerable Priestley. In the Appendix to his last chemical work, he thus expresses himself:— "When some progress was made in printing this work, (The Doctrine of Phlogiston established) I met with Dr. Beddoes' Contributions to Physical Knowledge, and in it, Mr. H. Davy's Essays, which have impressed me with a high opinion of his philosophical acumen. His ideas were to me new, and very striking, but they are of too great consequence to be decided upon hastily."

Considering these Essays dispassionately after a lapse of forty years, the chief fault of them was, decidedly, that which their Author almost immediately perceived, namely, hastiness of generalisation,—and the apparent presumption indicated by it. As regards the speculations themselves in which they abound, though some of them were ingenious and may be true, many of them, it must be allowed, were wild, and probably visionary; but, on that account, they are not uninstructive; they strongly shadow forth the infant mind of the Philosopher; the wildest of them are most natural to a young mind, just entering on (as it was to him) the twilight of physical science, gifted with high powers and a vivid imagination. In the infancy of science itself, there was the same disposition generally displayed, and in the highest degree; of which Alchemy and Astrology afford the strongest proofs. Moreover, the period of his noviciate was peculiar, marked by excitement and innovation, and the abandonment of the "*state super vias antiquas*;" the leaven of the French Revolution was still fermenting;—the mysterious phenomena of Galvanism had then recently been brought to light; the muscles of animals apparently dead had been made to contract by the new influence, as if re-animated; and pneumatic chemistry had just then been called to the aid of medicine, with a confident expectation of wonderful effects, deluding men of the soundest judgments. It is not remarkable, then, making allowance for these circumstances, that at the age of nineteen, he thus indulged in speculation; but it is very remarkable, how soon he saw his error, and ever afterwards avoided it—that is, the illegitimate use of speculation,—not having (to use an expression of his own) "its source in facts and its termination in experiments." Merely regarded as a phenomenon of mind, independent of the new facts and many ingenious views which they contain, these Essays, I cannot help thinking, will always be held to be curious and interesting, and deserving, in the way of reflection, of the attention both of the student and of the philosopher.]

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* In "Contributions to Physical and Medical Knowledge, principally from the West of England, collected by Thomas Beddoes, M.D."

† Nicholson's Journal, 4to. vol. iv. p. 395.

AN ESSAY

ON

HEAT, LIGHT, AND THE COMBINATIONS OF LIGHT.

A DESIRE of improvement, and a peculiar spirit of philosophical investigation, productive of the greatest discoveries in the most important sciences, have eminently characterised this century.

Philosophers, not contented with examining the associations of those complex perceptions, to which the metaphysicians have given the name of abstract ideas, have observed nature, discovered effects, and erected their theories upon trains of connected sensations, called facts.

From hence arises the superiority of present philosophical systems; though these systems are far from that perfection, which they appear capable of attaining by the new mode of investigation.

The sciences have not been equally improved; those dependent for their existence on experiment, and the observation of physical phænomena, though newly discovered, have made the most rapid advances towards perfection.

Chemistry, which arose from the ruins of alchemy, to be bound in the fetters of phlogiston, has been liberated, and adorned with a beautiful philosophic theory. The numerous discoveries of Priestley, Black, Lavoisier, and the other European philosophers in this branch of science, afford splendid proofs of the increasing energies of the human mind.

From the application of Chemistry to the discovery of the laws of organic existence, mankind had hoped to derive the greatest advantages; from this source they expected the perfection of physiological science; but their hopes have been in a great measure frustrated; and if we except the theories of a celebrated medical philosopher, Dr. Beddoes, it will be found that chemistry has as yet afforded but little assistance in the cure of diseases, or in the explanation of the laws of organic existence.

Our ignorance of the composition of organic matter, and of the changes effected in the blood by oxygen gas, is a considerable source of the imperfection of medicine. A more intimate acquaintance with those important parts of chemistry would tend, not only to the elucidation of that branch of philosophy, but to the production of the most beneficial effects in medicine and physiology, sciences of the utmost importance to man; sciences, from the perfection of which he may hope to eradicate a great portion of the physical and moral evil to which he is subject.

Light has been heretofore little considered in chemical theory; its affinities have never been investigated. A substance of the greatest importance to organic existence has been very little regarded, but in a physical view, as a stimulus, and as the source of the most numerous and pleasurable of our sensations.

The planetary motions, those wonderful phænomena, and the laws by which they are governed, appear to be designed for the express purpose of supplying the whole of the solar system with a certain necessary quantity of light.

The general analogy of nature, the wonderful simplicity of causes and complexity of effects, would alone tend to prove that this substance is subservient to other purposes than those of vision and vegetation. Since light and heat are usually concomitant, since there is rarely a considerable degree of one without the other, philosophers have questioned whether they are not cause and effect; and M. Lavoisier is one of these philosophers. He says:* "La lumiere, est elle une modification du calorique, ou bien le calorique, est il une modification de la lumiere?" I have made an experiment which seems to demonstrate directly that light is not a modification, or an effect of heat.

EXPERIMENT I.

A small gunlock was procured, armed with an excellent flint. This lock was elevated by means of two iron springs on the stand of the receiver of an air-pump. A slight iron wire was affixed to the trigger, brought through a hole made in the centre of the stand, and cemented into the hole with wax, so as to exclude entirely atmospheric air from the receiver. The receiver was exhausted, and the lock snapped; but no light was produced. The receiver was filled with carbonic acid, and the lock again snapped, with the same result; no light was produced. Small particles were separated from the steel, which on microscopic examination evidently appeared to have undergone fusion.*

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* Traité elementaire. t. 1. p. 6.

If light was a modification, or an effect of heat, it must have been produced in this experiment; since the heat generated by collision was sufficient to fuse steel, a degree of heat much above that improperly called a white heat.

Light then cannot be caloric in a state of projection.

Nor can it be, as some philosophers suppose, a vibration of the imaginary fluid ether. For even granting the existence of this fluid, it must be present in the exhausted receiver, and in carbonic acid gas, as well as in atmospheric air; and if light is a vibration of this fluid, generated by collision between flint and steel in atmospheric air, it should likewise be produced in the exhausted receiver, where a greater quantity of ether is present, which is not the case.

Since light is neither an effect of caloric, nor of an etherial fluid supposed to be extended through space,† and as the impulse of a material body on the organ of vision is essential to the generation of a sensation, light is consequently matter of a peculiar kind, capable when moving through space with the greatest velocity, of becoming the source of a numerous class of our sensations.

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* [This he afterwards doubted: *vide* "Extract of a letter, &c. to Mr. Nicholson," following these Essays, and his "Observations on the appearances produced by the collision of steel with hard bodies."]

† The philosophers who support this opinion suppose the universe a plenum; amongst these is the great Euler. It may not be amiss to observe on this subject, that to suppose the universe a plenum, and constituted a plenum by an elastic fluid, is absurd. It is essential to the elasticity of a fluid, that it be capable of compression; that is, of filling less space than it before existed in. Now as different bodies cannot exist at the same time in the same place, there must necessarily be a void space between the particles of an elastic fluid, such as ether is assumed to be, which overturns their hypothesis.

Matter is possessed of the power of attraction. By this power the particles of bodies tend to approximate, and to exist in a state of contiguity. The particles of all bodies with which we are acquainted, can be made to approach nearer to each other, by peculiar means, that is, the specific gravity of all bodies can be increased by diminishing their temperatures. Consequently (on the supposition of the impenetrability of matter) the particles of bodies are not in actual contact. There must then act on the corpuscles of bodies some other power, which prevents their actual contact; this may be called repulsion. The phænomena of repulsion have been supposed, by the greater part of chemical philosophers, to depend on a peculiar elastic fluid; to which the names of latent heat, and caloric, have been given. The peculiar modes of existence of bodies, solidity, fluidity, and gazity, depend (according to the calorists) on the quantity of the fluid of heat entering into their composition; this substance insinuating itself between their corpuscles, separating them from each other, and preventing their actual contact, is, by them, supposed to be the cause of repulsion.

Other philosophers, dissatisfied with the evidences produced in favour of the existence of this fluid, and perceiving the generation of heat by friction and percussion, have supposed it to be motion.*

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* It was foreign to the design of this essay to give the history of the opinions of the different philosophers on the cause of heat, as well as an account of the different experiments that have heretofore been made on it. The short view of the phænomena of repulsion given after the experiments on the cause of heat, is deduced from the experiments of Black, Crawford, and others, experiments which are too well known by chemical philosophers to need quotation.

Considering the discovery of the true cause of the repulsive power as highly important to philosophy, I have endeavoured to investigate this part of chemical science by experiments: from these experiments (of which I am now about to give a detail), I conclude that heat, or the power of repulsion, is not matter.

THE PHÆNOMENA OF REPULSION ARE NOT DEPENDENT ON A PECULIAR ELASTIC FLUID FOR THEIR EXISTENCE, OR CALORIC DOES NOT EXIST.

Without considering the effects of the repulsive power on bodies, or endeavouring to prove from these effects that it is motion, I shall attempt to demonstrate by experiments that it is not matter; and in doing this, I shall use the method called by mathematicians, reductio ad absurdum.

Let heat be considered as matter, and let it be granted that the temperature of bodies cannot be increased, unless their capacities are diminished from some cause, or heat added to them from some bodies in contact.

Now the temperatures of bodies are uniformly raised by friction and percussion. And since an increase of temperature is consequent on friction and percussion, it must consequently be generated in one of these modes. First, either from a diminution of the capacities of the acting bodies from some change induced in them by friction, a change producing in them an increase of temperature.

Secondly, or from heat communicated, from the decomposition of the oxygen gas in contact by one or both of the bodies, and then friction must effect some change in them (similar to an increase of temperature), enabling them to decompose oxygen gas, and they must be found after friction, partially or wholly oxydated.

Thirdly, or from a communication of caloric from the bodies in contact, produced by a change induced by friction in the acting bodies, enabling them to attract caloric from the surrounding bodies.

Now first let the increase of temperature produced by friction and percussion be supposed to arise from a diminution of the capacities of the acting bodies. In this case it is evident some change must be induced in the bodies by the action, which lessens their capacities and increases their temperatures.

EXPERIMENT II.

I procured two parallelopipedons of ice,* of the temperature of 29°, six inches long, two wide, and two-thirds of an inch thick: they were fastened by wires to two bars of iron. By a peculiar mechanism, their surfaces were placed in contact, and kept in a continued and violent friction for some minutes. They were almost entirely converted into water, which water was collected, and its temperature ascertained to be 35°, after remaining in an atmosphere of a lower temperature for some minutes. The fusion took place only at the plane of contact of the two pieces of ice, and no bodies were in friction but ice. From this experiment it is evident that ice by friction is converted into water, and according to the supposition its capacity is diminished; but it is a well-known fact, that the capacity of water for heat is much greater than that of ice; and ice must have an absolute quantity of heat added to it, before it can be converted into water. Friction consequently does not diminish the capacities of bodies for heat.

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* The result of the experiment is the same, if wax, tallow, resin, or any substance fusible at a low temperature be used; even iron may be fused by collision, as is evident from the first experiment.

From this experiment it is likewise evident, that the increase of temperature consequent on friction cannot arise from the decomposition of the oxygen gas in contact, for ice has no attraction for oxygen. Since the increase of temperature consequent on friction cannot arise from the diminution of capacity, or oxydation of the acting bodies, the only remaining supposition is, that it arises from an absolute quantity of heat added to them, which heat must be attracted from the bodies in contact. Then friction must induce some change in bodies, enabling them to attract heat from the bodies in contact.

Experiment III.

I procured a piece of clock-work so constructed as to be set to work in the exhausted receiver; one of the external wheels of this machine came in contact with a thin metallic plate. A considerable degree of sensible heat was produced by friction between the wheel and plate when the machine worked uninsulated from bodies capable of communicating heat. I next procured a small piece of ice;* round the superior edge of this a small canal was made and filled with water. The machine was placed on the ice, but not in contact with the water. Thus disposed, the whole was placed under the receiver, (which had been previously filled with carbonic acid,) a quantity of potash (*i. e.* caustic vegetable alkali) being at the same time introduced.

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* The temperature of the ice and of surrounding atmosphere at the commencement of the experiment was 32°, that of the machine was likewise 32°. At the end of the experiment the temperature of the coldest part of the machine was near 33°, that of the ice and surrounding atmosphere the same as at the commencement of the experiment; so that the heat produced by the friction of the different parts of the machine was sufficient to raise the temperature of near half a pound of

The receiver was now exhausted. From the exhaustion, and from the attraction of the carbonic acid gas by the potash, a vacuum nearly perfect was, I believe, made.

The machine was now set to work. The wax rapidly melting, proved the increase of temperature.

Caloric then was collected by friction; which caloric, on the supposition, was communicated by the bodies in contact with the machine. In this experiment, ice was the only body in contact with the machine. Had this ice given out caloric, the water on the top of it must have been frozen. The water on the top of it was not frozen, consequently the ice did not give out caloric. The caloric could not come from the bodies in contact with the ice; for it must have passed through the ice to penetrate the machine, and an addition of caloric to the ice would have converted it into water.

Heat, when produced by friction, cannot be collected from the bodies in contact, and it was proved by the second experiment, that the increase of temperature consequent on friction cannot arise from diminution of capacity, or from oxydation. But if it be considered as matter, it must be produced in one of these modes. Since (as is demonstrated by these experiments) it is produced in neither of these modes, it cannot be considered as matter. It has then been experimentally

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metal at least one degree, and to convert eighteen grains of wax (the quantity employed) into a fluid.

demonstrated that caloric, or the matter of heat, does not exist.

Solids, by long and violent friction, become expanded,* and if of a higher temperature than our bodies, affect the sensory organs with the peculiar sensation known by the common name of heat.

Since bodies become expanded by friction, it is evident that their corpuscles must move or separate from each other. Now a motion or vibration of the corpuscles of bodies must be necessarily generated by friction and percussion. Therefore we may reasonably conclude that this motion or vibration is heat, or the repulsive power.

Heat, then, or that power which prevents the actual contact of the corpuscles of bodies, and which is the cause of our peculiar sensations of heat and cold, may be defined a peculiar motion, probably a vibration, of the corpuscles of bodies, tending to separate them. It may with propriety be called the repulsive motion.†

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* Expansion by friction is common to almost all bodies; and as the exceptions are very few, it may be admitted as a principle. I have found by experiment, that the metallic substances, and the solid combinations of hydrogen, carbon, and oxygen, become enlarged in all their dimensions when heated by friction, and I believe all other bodies except ice, in which a new apposition of particles, and probably a new repulsive motion takes place.

† Heat, in common language, signifies that sensation which accompanies an increase of repulsive motion in any part of our system. It should not be used therefore for the repulsive motion or cause of that sensation.

The caloric of the French nomenclators is equally exceptionable; for having been generally used to express the imaginary fluid, or matter of heat, it is now associated with, and generally suggests that idea, and would thus if used to express the repulsive motion, or cause of heat, become a source of error. Words expressing compound ideas, should, when formed at will, express as near as possible the component parts of these ideas, when they are known. The word repulsive motion is, Since there exists a repulsive motion, the particles of bodies may be considered as acted on by two opposing forces, the approximating power, which may (for greater ease of expression) be called attraction, and the repulsive motion. The first of these is the compound effect of the attraction of cohesion, by which the particles tend to come in contact with each other, the attraction of gravitation, by which they tend to approximate to the great contiguous masses of matter, and the pressure under which they exist, dependent on the gravitation of the superincumbent bodies. The second is the effect of a peculiar motory or vibratory impulse given to them, tending to remove them farther from each other, and which can be generated, or rather increased, by friction or percussion. The effects of the attraction of cohesion, the great approximating cause, on the corpuscles of bodies, is exactly similar to that of the attraction of gravitation on the great masses of matter composing the universe, and the repulsive motion is analagous to the planetary projectile force.

Bodies exist in different states, and these states depend on the differences of the action of attraction, and of the repulsive power, on their corpuscles, or in other words, on their different quantities of attraction and repulsion.

When the attraction predominates over the repulsive motion, the body exists in the state of solidity. In this state its particles are relatively contiguous, consequently it exists in a relatively small space. It is difficultly divisible by mechanical means; and when divided,

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I believe, liable to no exception, I shall therefore use it to express the separating power of the corpuscles of bodies, and the cause of our sensation of heat.

its parts being brought into apparent contact, are incapable of aggregative union.

When the sum of the attractions of all the corpuscles is nearly equal to that of their repulsive motion, that is, when the attraction and repulsion are in equilibrio, the body exists in the state of fluidity. In this state it is difficultly compressible, and easily divisible by mechanical means, and when divided, its parts being brought into apparent contact, are capable of aggregate union.

When the repulsive motion predominates over the attraction, the body exists in the state of *gazity*, or elastic fluidity. Existing in this mode, it fills up great space; it is more easily divisible, and more capable of aggregative union than a fluid, and has the peculiar property of elasticity, that is, of great diminution of volume by compression, and of expansion by abstraction of compressing forces; so that its volume is in the inverse ratio of the compressing weights.

There is another state which has been heretofore unnoticed, and in which only one body that we are acquainted with exists, namely light.*

In this state the repulsive motion predominates to such an extent over the attraction, that the corpuscles indefinitely separate with the greatest velocity, and appear to be very little acted on by attraction or gravitation. This state may be called repulsive projection.†

Every body with which we are acquainted exists in one of these states, and appears capable of existing in either of them by the increase or diminution of the repulsive motion of its corpuscles. But though these are modes of existence common to matter in general, yet it appears that all bodies have different quantities of attraction and repulsive motion when existing in the same state. Different solids, fluids, and gasses are alike eminently different in their specific gravity, and this difference would induce us to suppose that the sums of the attractions and repulsive motions of their particles are different.

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* And probably odorous matters, as they appear to be continually flying off with great velocity from bodies.

† As this is a state of existence hitherto not particularly noticed, it was thought proper to distinguish it from other states by a peculiar name. In this state the repulsive motion predominates to such an extent over the attraction, that the particles are projected into space with the greatest velocity. The term repulsive projection will distinguish this state from others with ufficient accuracy, and from mechanical projection.

When bodies expand, we are certain that their repulsive motion is increased; when they contract, we are certain it is diminished; and we have no other infallible tests of an increase or diminution of repulsive motion, but expansion or contraction.

Bodies may have their repulsive motion increased in three modes.

First, By the transmutation of mechanical into repulsive motion, that is, by friction or percussion. In this case the mechanical motion lost by the masses of matter in friction is the repulsive motion gained by their corpuscles.

Secondly, By the motion of chemical combinations or decomposition.

Thirdly, From the communicated repulsive motion of bodies in apparent contact.

The disposition in bodies to communicate or receive the repulsive motion, has been called temperature, and the temperature of a body is said to be high or low in proportion as it communicates or receives the repulsive motion. The powers to communicate or receive the repulsive motion, as well as the velocities of communication or reception, are specifically different in different bodies, and, as far as we know, do not depend on the absolute quantities of repulsive motion, but on some peculiar atomic constitution now unknown to us. As it is found by experiment that the disposition of almost all bodies to communicate repulsive motion is increased by every addition of it as measured by expansion, and diminished by every subtraction as measured by contraction, the temperatures of bodies are generally made the measures of their relative quantities of repulsive motion.*

Different bodies have their temperatures, or their powers to communicate or receive repulsive motion differently increased by the addition, and diminished by the subtraction, of equal quantities of repulsive motion. This disposition is called, in the doctrine of caloric, their capacity for heat; but it might be named with greater propriety, their capability of temperature, for it has no relation to the absolute quantity of repulsive motion they are capable of receiving, but only to their temperature. All bodies, in fact, are capable of any increase of repulsive motion, but have their temperatures differently raised by this increase, that is, have different capabilities of temperature. The body then, that is said to have the greatest capacity for heat, has the least capability of temperature, and *vice versa*. The capability of temperature of bodies is diminished by the addition of repulsive motion, and increased by its subtraction; so that the capability of a body is greatest when solid, less when fluid, and least of all when in the gaseous, or repulsive projectile state.

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* A peculiar sensation known by the name of heat is consequent on an increase of repulsive motion in any part of our bodies, and an opposite one called cold, on a diminution of it. The common mode of determining the relative quantities of repulsive motion in bodies, is by appealing to these sensations. Philosophy uses the mercurial thermometer. The discovery of any mode of accurately determining the contractions and expansions of solids, would be a great acquisition to science.

The capability of temperature of bodies likewise depends on the degree of pressure under which they exist. When bodies are compressed, their capabilities are increased, and their temperatures raised; when pressure is removed from bodies, their capabilities are diminished, and their temperatures lowered.

When bodies in apparent contact communicate the repulsive motion, the motion gained or lost by one body is uniformly equal to that lost or gained by the other body, as measured by temperature.

When two similar and equal bodies are brought in contact, they acquire a common temperature by communication of their repulsive motion: and the common temperature is an arithmetical mean between the two original temperatures. When two unequal and similar bodies are brought in contact, if their temperatures are different, they will acquire a common temperature by communication, and the communicated repulsive motion will be consequently divided between them in proportion to their quantities of matter. If two bodies of different capabilities of temperature, and of different temperatures, be brought in contact, they will acquire a common temperature, and the communicated repulsive motion will be found divided between them in proportion to their quantities of matter, and their capabilities.

When bodies combine chemically, it generally happens that the capability of the compound is different from that of either of the constituents. Hence in chemical combinations, the capabilities of bodies are either increased or diminished. When the capabilities of bodies are increased by chemical combination, the temperature of the compound is greater than that of the constituents. When the capability of the compound is less than that of the constituents, its temperature is diminished.

To ascertain the causes of the increase or diminution of temperature consequent on chemical combination, is by far the most difficult part of the philosophy of heat. For we are hardly able to distinguish the increase of temperature in bodies generated by the motion of combination, from that generated by increase of capability, and the motion of combination interferes with the diminution of temperature, from diminution of capability; and chemical processes are in general so complex, that we cannot distinguish between the increase of repulsive motion from composition, and that arising from decomposition.

We have every reason to suppose from the foregoing experiments and observations, that the repulsive power of bodies is a peculiar motory impulse. To distinguish this motion from others, and to signify the cause of our sensations of heat, &c. the name *repulsive motion* has been adopted.

On the theory of caloric, a peculiar elastic fluid was supposed to exist between the particles of all bodies; and the peculiar modes of existence of bodies, that is, solidity, fluidity, and gazity, were supposed to depend on the different quantities of caloric entering into their composition. The elasticity, that is, the compressibility of this fluid, has been universally admitted, and the compressibility of the gases has been supposed to depend on the compressibility of their caloric.

Now since caloric is supposed compressible, that is, capable of having its volume diminished by pressure, its particles cannot be in actual contact; there must consequently act on them some power which prevents their actual contact, that is, the repulsive motion. So that to admit the existence of an imaginary fluid in conformity to the absurd axiom, *bodies cannot act where they are not,* is in fact the solution of a small difficulty by the creation of a great one. After all, a principle must be admitted, (that is, repulsion); to do away the necessity of which, caloric has been invented.

On the theory of repulsive motion, it is evident that the gases (which M. Lavoisier and the French nomenclators have assumed to be simple substances combined with caloric) must be either simple substances in the state of elastic fluidity, or combinations of two or more simple substances. Hydrogen and nitrogen gas we have not yet been able to decompose; they are then relative to the present state of our knowledge, simple substances. Oxygen gas, as will be hereafter proved, is composed of light and oxygen.

Since the word gas adopted by the French nomenclators is intended to express the chemical combination, or rather the saturation of bodies with caloric, it is doubtless exceptionable. The following arguments will, I think, prove that it ought not to remain in the chemical nomenclature.

For first, bodies, when rendered from solids to fluids, from fluids to gases, are not essentially altered, their corpuscles are farther separated, that is, they move in greater space than before; but the body is equally simple, it has undergone no decomposition or combination; the word then that expresses the chemical combination of bodies with caloric is improper.

Secondly, All bodies with which we are acquainted have certain quantities of repulsive motion; and they have different modes of existence dependent on their quantities of repulsive motion. The most common of these modes are solidity, fluidity, and gazity; in each of these states the bodies are equally simple. The state in which they are found at the common temperature of the atmosphere, is the state from which they derive both their common and philosophic names. Now the French nomenclators have called all simple substances (the gases excepted) by their common names, without making any alteration to express their combination with caloric. They have called all the metals, which are capable of existing like other bodies, in three states, by their common names; and on their own principles these bodies are combined with caloric. They should therefore have distinguished them by names expressing this combination, and have called gold, mercury, and sulphur, solid gold, fluid mercury, and solid sulphur, for the same reasons that they have given the names of hydrogen and azotic gas to the mephitic and inflammable airs, which are probably metals in the state of elastic vapour.*

Thirdly, Those substances which have been called gases, uniformly exist in the state of elastic fluidity, at the common temperature of our planet. Simple names, without the addition of gas, would distinguish them from all other substances. With the same propriety that we use the term hydrogen gas in chemistry, we might make use of the terms, solid gold, fluid mercury, and fluid alcohol. In treating of the changes made in bodies by the repulsive motion, we may with propriety use the terms solid, fluid, and gaseous, to express the different modes of existence of the same body. But simple substances should be distinguished by names characteristic of their properties; compound substances should be distinguished by names expressive of the combination, that is, of the substances forming the compound. In conformity to these principles, I shall omit any names signifying the peculiar modes of existence of bodies; treating of substances, I shall give them their simple names, and by these names I mean to express the state in which they exist at the common temperature of the atmosphere. As for example, in using the words gold, mercury, and hydrogen, I mean solid gold, fluid mercury, and gaseous hydrogen. Oxygen gas, (which the French nomenclators have assumed to be oxygen combined with caloric) will be proved to be a substance compounded of light and oxygen. It would be highly improper to denote this substance by either of the terms oxygen gas, or oxygen. The one would signify that it was a simple substance combined with caloric, the other that it was a simple substance, the acidifying principle. The term *phosoxygen* (from *φως* light, *οξυς* acid, and *γενητωρ* generator) will I think be unexceptionable; it will express a chemical combination of the simple substance light, with the simple substance oxygen; it will not materially alter the nomenclature of the French philosophers; and as will be seen hereafter, it can be easily modified to express, in conjunction with other words, the combinations of light and oxygen.*

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* [This idea he afterwards often reverted to. The following remarks relating to it occur in a Lecture of 1808.—"Concerning the aspect of hydrogen and nitrogen, could they be obtained in the solid or fluid form it is impossible to reason, since there is no probability that we shall be able to condense or compress them into these states; but their elastic form is no proof that their nature is not metallic. Mercury, zinc, and arsenic, are all aëriform bodies at the red heat; and at this temperature, as I have found by several experiments, they are like the other gases, non-conductors of electricity; they are in short, peculiar species of inflammable air."]

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* [Referring to the new terms which he had used in these essays, shortly after their publication, he remarks:—"I would wish to observe, that no affectation of singularity induces me to use a new nomenclature.

OF LIGHT.

Light is a body in a peculiar state of existence. Its particles are so amazingly minute, that they are very little affected by gravitation; and pass unaltered through the pores of diaphanous bodies. They move through space with a velocity almost inconceivable, and communicate no perceptible mechanical motion to the smallest perceptible particles of matter.* From the peculiar velocity of light we estimate its quantity of repulsive motion. The influence of the attraction of gravitation on light is very small, as is evident from its not apparently gravitating towards the sun or the earth. The influence of the cohesive attraction on its particles is likewise very small, as is evident from their uniform separation, &c.; but the repulsive motion acting on the corpuscles of light is very great, as is apparent from their velocities, and continual separating motion. But as we have said before, the distances of the corpuscles of bodies from each other, and the velocities of their motions, are in a ratio compounded of their repulsive motion and attraction. When the repulsive motion eminently predominates over the cohesive and gravitative attraction, the particles of matter will indefinitely separate, as those

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Theory or arrangement of facts depends altogether on language, i. e. in applying certain general terms to a number of similar ideas, or similar trains of ideas; consequently there cannot well be a new theory without a new nomenclature. Till my experiments on heat and light are rendered inconclusive, by numerous contradictory facts, or experiments, I consider myself as entitled to use my present nomenclature for the combinations of light."—Nicholson's Journal, 4to. vol. iii. p. 55.]

* It will be by and by proved that they communicate portions of their repulsive motion to the corpuscles of bodies.

of light. To distinguish this state of existence, peculiar to light, from those other bodies, we have given it the name of *repulsive projection.*

Light is the source of the most numerous and pleasurable of our perceptions. This tribe of perceptions is thus received; particles of light in the state of repulsive projection coming in contact with the retina, communicate to it portions of their repulsive motion. The retina appears to be composed of nervous medulla and, as some suppose, of irritable fibre. The communicated motion of light either stimulates the irritable fibre into contraction, which contraction is accompanied with that affection of the nerve corresponding to a sensation: or the motion of light communicated to the nerve itself produces the sensorial affection. The former of these opinions is rendered probable by the experiments of Dr. Darwin on ocular spectra.* It is then necessary to our perceptions of light, that it exist in its peculiar state of repulsive projection; we consequently cannot perceive it by vision in any other mode of existence.

It appears from experiment that our sensations of vision are occasioned by the united impulse of a number of particles of light both synchronically and successively falling on the retina. All our different sensations then must arise from differences in the particles of light, their motions and numbers, or from differences in some of these.

Light passing through diaphanous bodies, is attracted by their particles, and the attraction of the particles of bodies for light is proportional to their density and combustibility. The laws of the attraction of diaphanous bodies for light are the laws of refraction which have been so admirably explained by the immortal Newton.

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* See the end of Darwin's Zoonomia, vol. i.

He discovered that the particles of solar light are not equally attracted in passing through different bodies: they are differently refracted in passing through the prism, and separated into seven classes of particles that produce the sensations of red, orange, yellow, green, blue, indigo, violet. This difference is easily accounted for, by supposing that the particles of light in taking the state of repulsive projection, originally received a different repulsive motion. The red particles being supposed to vibrate with the greatest velocity, must be least attracted by the particles of the medium through which they pass; the violet particles moving with the least velocity, must be most refracted, and the different velocities of the intermediate coloring particles being supposed, their different refractions must be correspondent, which is found to be the case.

Light is reflected from bodies that it cannot penetrate or combine with. The sensations we receive from reflected light are eminently different. A correspondence has been long observed between the colors of bodies, and the increase of repulsive motion in them from the action of light. This correspondence is a subject of great importance to physical science, and worthy of investigation. Heat has been proved to be a peculiar repulsive motion of the particles of bodies. Light is a body, the particles of which are acted on by the greatest repulsive motion. When a body has its repulsive motion increased by the action of light, a portion of the repulsive motion of light must be lost, a portion equal to that gained by the body acted on; this is evident from what has been said on the communication of repulsive motion in the doctrine of heat.

To determine accurately the correspondence between the increase of repulsive motion in bodies from the action of light, and their colors, I made the following experiment:—

EXPERIMENT IV.

Six similar pieces of copper,* of equal weight, size, and density, were thus colored, one white, one yellow, one red, one green, one blue, and one black. A portion of a mixture of oil and wax, which became fluid at about 76°, was placed on the centre of each on the inferior side. They were then attached to a board painted white, and so placed with regard to the sun, that their upper surfaces were equally exposed to the light. Their inferior surfaces, to which the cerate was attached, were equally deprived of light and heat, that is, they were so exposed that there could be no mistake with regard to the repulsive motion generated in them by the action of light. The changes of temperature in them from the action of light, took place in the following order. The cerate on the black plate began to melt perceptibly before the rest, the blue next in order, then the green and the red, and lastly the yellow; the white was scarcely at all affected when the black was in a complete state of fusion.

This experiment proves that the increase of repulsive motion in bodies from the action of light, is great in proportion as the colors are dark. Now as our sensations arise from the united impulse of a number of particles on the retina, in proportion as the vibratory motions of these particles are greater or less, so in proportion must our sensations be different.

It does not appear that reflected light is in any instance composed of particles that have equal quantities of repulsive motion; the differences of sensations therefore most probably arise from the differences occasioned in the vibrations of all the particles, from their communicating to the reflecting bodies portions of their repulsive motion, and not from the communication of the greater portion of that of some of the particles, that is, of those which are supposed in the Newtonian system to be absorbed. On this supposition the light reflected from white bodies (which may be said to have the least capability of subtracting the repulsive motion of light) must vibrate with the greatest velocity, that is, must be reflected nearly unaltered. The particles reflected from dark bodies (which may be said to have the greatest capability for receiving the repulsive motion of light) communicating great portions of their repulsive motion, must vibrate with the least velocity, and all the intermediate colours may depend on the different velocities of vibration. Their vibrations, though of different lengths, may be isochronous, and all the particles may pass through rectilineal space in equal times.

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* Each a cubic inch square, and two lines thick.

Bodies perfectly black must subtract so much of the repulsive motion of light, as to deprive it of its repulsive projectile form. The electric fluid is probably light in a condensed state, that is, not supplied with the repulsive motion sufficient to give it repulsive projection. Its chemical action upon bodies is similar to that of light, and when supplied with repulsive motion by friction, or the contact of bodies from which it is capable of subtracting it, it takes the repulsive projectile form, and becomes perceptible as light.*

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* [Some facts recently discovered might be adduced in favour of the above view,—especially the results of Mr. Pearsall's experiments on the property which belongs to electricity of imparting phosphorescence to bodies. He found that many bodies not phosphorescent might be ren-

Though the temperature of the atmosphere, which is found proportional to the light passing through it, may in some measure depend on the repulsive motion communicated to it by opaque colored bodies; yet it is reasonable to suppose that the particles of light in passing through the atmosphere, lose small portions of their repulsive motion, which is the great cause of the atmospheric heat. Water, glass, and other transparent bodies, are capable of having their repulsive motion increased by the action of light; and light in passing through them becomes coloured independent of decomposition. A body perfectly white appears colored in deep water, and Dr. Halley, when in the diving bell, found that his hand, exposed to the solar light, became of a deep red. Is not

dered so, by passing through them an electrical discharge;—and that bodies deprived of phosphorescence from the effect of heat,—recovered their phosphorescence or power of emitting light by being electrified.]—*Annales de Chimie et Phys.* tom. 49.

[The idea expressed above of the conversion of light into the electric fluid was amplified by the author in the original text;—thus, he remarks:—"It is extremely probable that the great quantity of this fluid almost every where diffused on our earth, is produced from the condensation of light, from the subtraction of its repulsive motion by black and dark bodies. This fluid continually formed from the condensation of light, is probably again supplied with repulsive motion at the poles, by the revolution of the earth on its axis, and given off in the form of repulsive projectile light, whilst a quantity equal to that given off from its equilibrating principle is supplied continually from the other parts of the globe. Hence the phænomenon of the aurora borealis, or northern lights. No more sublime idea can be formed of the motions of matter, than to conceive that the different species are continually changing into each other. The gravitative, the mechanical, and the repulsive motions, appear to be continually mutually producing each other, and from these changes all the phænomena of the mutation of matter probably arise." Such vagueness of generalization was very characteristic of his "infant speculations," as was also the direction in the *errata* to strike out the passage, of the rapid progress he was then making to a sounder logic.]

the blue colour of the air a proof that the repulsive motion of light is diminished in passing through it? May not the atmospheric temperature, and the refraction of light in it be in a great measure owing to the water held in solution by the air, for the temperature is lower in proportion as we advance higher in the atmosphere, and refraction does not take place above forty-five miles high, and we are certain from the phænomena of fiery meteors, that the atmosphere extends at least as high again.

On the above mentioned supposition, all our infinitely different sensations from reflected light must arise from differences in the numbers and repulsive velocities of the particles, and all light, if we may appeal to our sensations, must be in some measure altered both by reflection and refraction.

Bodies that do not contain light in combination, and that are incombustible, under certain circumstances become luminous.

To discover the cause of the luminous appearance of incombustible bodies, it is necessary to consider the circumstances under which it takes place. When glass, silex, argil, a metallic oxyd, or any other incombustible body, is exposed to a strong light, as the focus of a lens, its temperature is gradually raised, that is, its repulsive motion is increased. After a certain time it becomes luminous, white, or red hot; and if it be now removed out of the focus, it continues for some time to give out light, and to communicate repulsive motion to the surrounding bodies, till the equilibrium of temperature is restored.

Now when bodies have their repulsive motion increased by the action of light, it is evident that the motion gained by the body is that lost by the light;

and as a certain quantity of repulsive motion is essential to its repulsive projection, it must, after considerable communication of repulsive motion, cease to exist in that state. In its new state of existence it is probably not perceptible to any of our senses. We therefore in this case can only reason from its effects. The body continues for some time to give off light, after being removed out of the focus; light therefore must have been condensed in some form around it, and being gradually supplied with repulsive motion from the body, flies off slowly in the repulsive projectile form, becomes perceptible as light, and is the cause of the peculiar sensation known by the name of red or white heat.*

From what has been said, it is evident that light, both in the state of repulsive projection, and in the form of the electric fluid, performs an important part in the physical phænomena of the universe. In any other states than these, we have not hitherto been able to detect it by the senses; but we know not what we may be enabled to accomplish by means of a more extensive and philosophic chemistry. A number of the elements are already in our power, and the rapid progress of the perfection of science seems to promise us the knowledge of those etherial fluids, which at present elude the perception of our organs, and are only known by their effects.

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* This theory of the luminous appearance of incombustible bodies may be compared with Macquer's and Newton's. Fourcroy says, " L'incandescence des corps incombustibles, telles que les pierres dans lesquelles on ne peut point admettre la presence de la lumiere combinée, au moins comme dans les corps incombustibles, a été expliquée, d'une maniere tres ingeniuse par Macquer. Suivant ce chemiste, elle depend des vibrations fortes, excitees dans les molecules de ces corps par la chaleur; ces vibrations dispose les particles de sorte que leur facettes, sans cesse agitees sont autant de petit miroirs qui reflechissent vers nos yeux les rayons de lumiere, qui existent dans l'air pendant la nuit autant que pendant le jour, et qui ne sont insensibles, et ne produisent les tenebres que parceque leur direction ne se fait pas sur les organes de la vue."—*Fourcroy, Elem.* t. 1. p. 127.

The immortal Newton says, " Do not all bodies when heated beyond a certain degree emit light and shine, and is not this emission performed by the vibratory motions of their parts," &c.—See 8, 9, and 10 queries at the end of his optics. The first experiment appears to overturn the foundation of these theories.

The chemical effects of light are not less important than the physical. Its combinations, hitherto almost unnoticed, have the highest connection (as will be seen hereafter) with organic existence; and the most astonishing and beautiful of the chemical phænomena depend upon them.

Light enters into the composition of a number of substances. In some of these, the incombustible phosphorescent bodies, it most probably exists in a state of loose combination, and the presence or absence of light does not appear to alter their properties materially. In *phosoxygen* (oxygen gas) it is intimately combined with oxygen.

OF THE COMBINATIONS OF LIGHT.

OF PHOSPHORESCENT BODIES.

Certain bodies, after being for some time exposed at a high temperature to light, continue luminous for a considerable length of time after this exposure. Such are many preparations of lime, the bolognian stone, &c. This phænomenon is in some measure analogous to the ignition of incombustible bodies.

Light, it appears, is only susceptible of combining, and of remaining in combination with those bodies at a higher temperature than that of our atmosphere; at the common temperature it is liberated.

The name of solar phosphori has been given to these bodies, in common with all others that become luminous, independent of combustion.

Other bodies exist, which become luminous when their repulsive motion is increased by communication of it from some bodies of a higher temperature. Light remains in combination with these bodies only at a low temperature. When their repulsive motion is increased, the light is liberated. This decomposition appears to arise from the diminution of the chemical attraction between light and the body, by the repulsive motion, and from the supply of a quantity of it sufficient to enable light to fly off in the repulsive projectile form. Amongst these bodies are the different combinations of lime, and particularly the fluate, (the colours of which appear to depend upon combined light,) different combinations of barytes, the sulphate of potash, some of the metallic oxyds, cotton, wool, oils, wax, alcohol, &c. We owe the discovery of the greater number of these phosphorescent bodies to Mr. T. Wedgwood.* We have found that the sulphate of strontian, on an increase of temperature, gives out a pale light.

There is a class of phosphorescent bodies, which give out their combined light on attrition. Amongst these are borate of soda, sulphate of argil, tartrite of potash, and all the silicious class of stones.† This phosphorescence may be accounted for in the same manner as the last species.

Certain substances give out their combined light on immersion into the mineral acids. When magnesia‡ is thrown into the sulphuric acid, a light is liberated which produces a sensation similar to that known by the name of red heat. The same effect is produced when the nitric acid is used.

During the combination of lime with the mineral acids, a flash of white light is uniformly perceived; the same effect is not produced during the combination of strontian and barytes with these acids.

This phænomenon appears to be owing both to the attraction of the acids, and to the repulsive motion generated during the combination, a motion sufficient to give to the combined light repulsive projection; for lime and magnesia become luminous when heated, which is not the case with strontian and barytes.

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* See his ingenious paper in the Phil. Trans. for 1792.

† For a further account of these bodies, see the same paper of Mr. T. Wedgwood.

‡ I was informed of this phænomenon by Dr. Beddoes, who had previously witnessed it several times.

It is probable that some of the combustible bodies are phosphorescent. From an experiment of the Dutch chemists it appears that sulphur in its common state contains light. This experiment, which has been the subject of much speculation, has been several times repeated by Mr. Clayfield,* (and once in my presence) with results different from those mentioned by the discoverers. When copper and sulphur cautiously freed, and included from phosoxygen (oxygen gas) were made to combine by the heat of an argand lamp, a luminous appearance was perceived during the combination, and a considerable quantity of an incombustible gas, mingled with sulphureous acid, was liberated.

Phosphorus appears to contain light. Mr. Clayfield has often made me observe, during the combination of phosphorus and the earths, a fine vivid light, wherever the phosphoric vapour came in contact with the earths heated red.

The supposition that the combustible bodies are phosphorescent, may in some measure reconcile the phlogistic and pneumatic theories with each other.

The phosphorescence of certain insects and putrifying animal substances will be treated of in the theory of respiration.

All the above mentioned phænomena equally take place in any gas, and appear to be perfectly independent of combustion.

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* It is to be hoped that this ingenious chemist will soon publish a particular account of it.

OF PHOSOXYGEN, OR OXYGEN GAS.

This gas (first discovered by the immortal Priestley) the great Lavoisier supposed to be oxygen combined with caloric, and on this supposition his theory of combustion is founded. The non-existence of caloric, or the fluid of heat, has been proved, and the materiality of light demonstrated.

Light is liberated during the oxygenation of certain bodies, as the following experiments will prove.

EXPERIMENT V.

The repulsive motion of carbon in contact with phosoxygen (oxygen gas) was increased by a burning glass, till it became luminous; the carbon was rapidly diminished with the liberation of a great quantity of light; the temperature of the glass globe containing the phosoxygen (oxygen gas) was very much increased, and a very small diminution of weight* was perceived.

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* The following mode of ascertaining the diminution of weight was adopted in these experiments. The combustible body was suspended in a small earthen cup, in a glass globe filled with phosoxygen. This globe was heated to dry it perfectly, attached to a balance, and accurately weighed before combustion. The combustible body was fired by a burning-glass. During combustion the globe always rapidly ascended from the rarefaction of the surrounding atmosphere. After combustion, when the common temperature was restored, there appeared an evident small diminution of weight. This diminution was too small to be exactly ascertained by the balance I made use of, and appeared to be different in different processes.

[It is hardly necessary to observe, that in this and the following instances, in which it was supposed that there was a loss of weight from the emission of light in combustion, the author was in error, probably deceived by the imperfection of his apparatus and mode of experimenting.]

The phosoxygen (oxygen gas) and carbon were almost entirely consumed, and a quantity of carbonic acid was formed, apparently nearly equal to the carbon and phosoxygen.

Experiment VI.

The temperature of phosphorus in contact with phosoxygen was raised by a burning glass: it immediately became luminous. An immense quantity of light was liberated, and the temperature of the surrounding bodies very much increased. A deficiency of weight was observed, a deficiency more considerable than I have found in any other combustible process; and phosphoric acid nearly equal to the phosoxygen and phosphorus was formed.

Experiment VII.

Sulphur was heated in phosoxygen. It rapidly diminished with the liberation of a great quantity of light, and great increase of temperature in the surrounding bodies. After combustion a small deficiency of weight was found; and sulphuric acid nearly equal to the sulphur and phosoxygen employed, was formed.

Experiment VIII.

The temperature of hydrogen in contact with phosoxygen was raised. The gases were diminished with great liberation of light, and great increase of temperature; and water nearly equal to them was formed.

Experiment IX.

Zinc was heated in contact with phosoxygen; it became luminous, and was consumed with a white brilliant flame. The substance remaining after combustion was white oxyd of Zinc.

Experiment X.

A small gun-lock, armed with an excellent flint, was snapped in a vessel filled with phosoxygen. The sparks of light arising from the particles of steel separated by collision, were the most brilliant that can be imagined; and these particles examined by a magnifier, were found converted into black oxyd of iron.*

From these experiments, it appears that in the chemical process of the formation of many oxyds and acids, light is liberated, the phosoxygen and combustible base consumed, and a new body formed, with properties essentially different from the substances entering into the combination. Since light is liberated in these processes, it is evident that it must be liberated either from the phosoxygen or from the combustible body. It appears, as we have before said, that small portions of light are contained in some of the combustible bodies; but it appears to be accidental, and common to them with incombustible bodies; for their properties are not apparently altered when it is driven from them by increased repulsive motion; and we have no reasons for supposing that carbon, hydrogen, or any of the metals contain the smallest portions of light.

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* This experiment, compared with the first, will afford a strong proof, not only of the composition of phosoxygen, but likewise of the doctrine of repulsive motion.

If the light liberated in combustion be supposed (according to Macquer's and Hutton's theories) to arise from the combustible body, then phosoxygen must be considered as a simple substance; and it follows on this supposition, that whenever phosoxygen combines with combustible bodies, either directly or by attraction from any of its combinations, light must be liberated, which is not the case, as carbon, iron, and many other substances, may be oxydated by the decomposition of water, without the liberation of light.

These experiments will appear more conclusive when the synthetic experiments are considered, and the whole theory examined. It appears that whenever bodies simply combine with oxygen, light is liberated. There are bodies that combine with oxygen and portions of light, as will be hereafter proved, and others that combine with phosoxygen.

Combustion is a complex chemical process. The decomposition of phosoxygen by the attraction of a body for oxygen. The light is generally liberated in the repulsive projectile form, and the oxygen combines with the attracting body to form an oxyd or acid. The great increase of temperature arises from the diminution of capacity in the combining bodies, from the repulsive motion generated during the combination, and from the concentrated liberated light.

It is probable that there are some decompositions so slow, that the generated repulsive motion is not sufficient to give to light repulsive projection. A few metallic oxydations appear to be of this nature.

The light liberated in different combustive processes, assumes very different appearances. During the combustion of bodies that remain solid or fluid at the temperature of combination, the sensation given by the liberated light is that which has been called a red or white heat. If the combustion proceeds but slowly, the red heat is produced, if more rapidly, the white. In the combustion of bodies that are gaseous, at the temperature of combination, the sensation known by the name of flame is produced by the liberated light. These different sensations depend, most probably, on the rapidity of combustion. The light must be liberated slowly when phosoxygen is decomposed by solids or fluids, and much more rapidly in the decomposition of gases.

The differences in the colors of the liberated light, must arise from different repulsive velocities given to the particles.

Since light and heat are totally distinct, it is evident that the names red and white heat, are improper, as applied to different modifications of light. Philosophy demands a more unequivocal nomenclature. The red and white heat might be called red and white slowly liberated light. As flame is a single word that can signify nothing but a modification of light, it may with propriety be retained in physical language.—To explain the phænomena of combustion, on their theory, the phlogistians were obliged to consider all combustible bodies as combinations of different unknown simple substances with the undemonstrated phlogiston; and phosoxygen, or vital air, a simple substance. This theory tended to confuse science, by referring to many unknown substances, to account for phænomena which evidently depend upon known ones. The phænomena of combustion, and the generated increase of temperature, are easily explained on the theory of repulsive motion, and on that of the composition of phosoxygen, and only one unknown principle is admitted, namely, oxygen, which we have never been able to obtain in its simple state, on account of its strong attraction for light and other substances; but whose existence is perfectly demonstrable.

The theory of the immortal Lavoisier and the ingenious French nomenclators will ever be admired by chemical philosophers. It appears, indeed, to be possessed of these defects alone: the assumption of the imaginary fluid caloric, the total neglect of light. According to the calorists, combustion ought always to take place when the gases are condensed; but it is found that none of the gases, (except those of which phosoxygen is a component part) however rapid their combinations or decompositions, produce the smallest combustion, or liberation of light, when ammonia and carbonic acid (whose united capacity is much greater than that of phosoxygen and phosphorus) combine, no combustion is produced, and the increase of temperature is less than might be expected from so great a contraction of volume.

The proofs of the composition of phosoxygen founded on synthetical experiments, are no less conclusive than those deduced from the analytical ones. *It will appear that the presence of light is absolutely essential to the production of phosoxygen from pure oxyds and acids.*

Of those substances that have been heretofore distinguished by the common name of oxygen attractors, there are some, as has been before said, that wholly decompose phosoxygen by attracting the oxygen, with which they combine, whilst the light is liberated. These oxyds are difficult of decomposition by light alone, as is reasonable to suppose, and if at all, at a much higher temperature than of that of their combination with oxygen. The oxyd of lead is decomposable with less light, and with less increase of repulsive motion, than probably any of the other oxyds, as will appear from the following observation:—

OBSERVATION *a*.

When pure oxyd of lead is heated as much as possible, included from light, it remains unaltered; but when exposed to the light of a burning-glass, or even of a candle, phosoxygen is generated, and the metal revivified.

In this process it is necessary that the temperature of deoxydation be greater than that of oxydation, as oxygen, at a certain temperature, has a stronger attraction for lead than for light; but at a higher temperature, it attracts light stronger than lead.

But few experiments have heretofore been made on the revivification of metallic oxyds by the simple application of heat and light. In the common processes they are restored by placing them in contact with bodies that have a stronger attraction for oxygen.

From the observation on the pure oxyd of lead, and those which have been made on the other oxyds, it appears that light is absolutely essential to the generation of phosoxygen from pure oxyds, and that phosoxygen is never produced from them, but when light is present.

The substances that partially decompose phosoxygen, that is, that combine with oxygen and portions of light, are more easily decomposable by light. The attraction between the base and oxygen is weakened by the attraction of light for oxygen; and the addition of a small quantity of light effects the decomposition; phosoxygen is formed, and the phosoxydable base remains pure, as the following observations will prove.

Observation *b*.

Oxygenated muriatic acid is a compound of muriatic acid, oxygen, and light, as will be hereafter proved. The combined light is not sufficient to attract the oxygen from the base to form phosoxygen; but its attraction for oxygen renders the acid easily decomposable. If this acid be heated in a close vessel, and light excluded, no phosoxygen is formed; but if it be exposed to the solar light, phosoxygen is formed, the acid loses its oxygen and light, and becomes muriatic acid.

Now since light, by producing repulsive motion cannot, as is evident from the first part of the last experiment, decompose oxygenated muriatic acid, it is evident that it must act chemically, that is, by combination; it must attract oxygen and light from the acid, and this combination is phosoxygen.

Observation *c*.

If nitric acid, which is compounded of oxygen light, and nitrogen, (as will be hereafter proved) is exposed to the solar light, phosoxygen is formed, and the acid reduced to the state of nitrous acid, that is, is deprived of a portion of its oxygen and light.

Observation *d*.

The yellow oxyd of tungsten consists of a peculiar metallic base, oxygen, and probably a small portion of light. If this oxyd be exposed to the solar light, phosoxygen is produced, the oxyd loses weight, and becomes blue.

OBSERVATION *e.*

The green prussiate of iron, exposed to the solar light, gives out phosoxygen, and becomes blue.

OBSERVATION *f.*

If the oxyds of gold or silver be exposed to the solar light, phosoxygen is produced, and the metals deoxydated.

From these observations it appears that light is essential to the production of phosoxygen from oxyds and acids; and the quantity of light essential, appears to be inversely proportional to the quantity contained in the combination. The substances that contain portions of light combined with their oxygen, are easily revivified by a small quantity of light, and a small increase of repulsive motion. The compounds, on the contrary, that are pure oxyds, that is, which contain no light, as the oxyds of iron, nickel, &c. require large portions of concentrated light, and a great increase of temperature, to produce from them phosoxygen.

Certain combinations of oxygen cannot be decomposed by the simple elective attraction of light for oxygen. These require for their decomposition the united force of two attractions: that of light for oxygen, and of some substance for the oxydable base.

Among these substances are water and carbonic acid.

Water, as is proved by the tenth experiment, is composed of oxygen and hydrogen. When the oxygen of phosoxygen combines with hydrogen to form water, light is liberated. Water is decomposed by two attractions; that of light for oxygen, and of a certain hydrogen attractor for hydrogen.

The marine cryptogamiæ, vegetables, and a number of other substances, attract hydrogen. That the marine cryptogamiæ* attract hydrogen, is evident from their analysis. I have found that they afford, when decomposed by repulsive motion, amongst other products, a considerable quantity of hydrogen. This hydrogen, as they are nourished entirely by water, or by substances held in solution by water, it is reasonable to suppose they somehow gain from the decomposition of water. To remove all doubt, however, concerning the attraction of the marine cryptogamiæ for hydrogen, I made the following experiment.

Experiment XI.

One cubic inch of conferva fœniculacea was put into a vessel containing thirteen cubic inches of hydrogen. It remained in a temperature of 58° for six hours, and at the end of that time was examined. The hydrogen was diminished eight-tenths of a cubic inch. I could get no balance sufficiently accurate to determine the weight gained by the plant.

As the marine cryptogamiæ cannot be obtained perfectly dry in their vegetative state, it was necessary to prove that the hydrogen gas diminished was not absorbed by the water in contact with the plant. For this purpose two phials, containing each 13½ cubic inches, were filled with hydrogen. One cubic inch of conferva fœniculacea was inserted into the one, and two cubic inches of wool, previously wetted, into the other. The quantity of gas in each of them was then accurately determined. The phials were inverted in the same vessel of water, and at the end of twelve hours examined. The diminution of the conferva was near a cubic inch and quarter; by the wool and water, not more than three-tenths of an inch.

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* I have preferred giving an account of the decomposition of water by the marine cryptogamiæ, to that effected by the vegetation of land plants, both as it is a fact heretofore unknown, and as, from the inferiority of their organic powers, their chemical attraction may be more readily admitted.

This experiment proves that the marine cryptogamiæ attract hydrogen; but their attraction is weaker than the attraction of oxygen for hydrogen, as it is found that seaweeds, or vegetables of any kind, placed in contact with water, and deprived of light, effect no alteration in it as long as they retain life. Water, consequently, is not decomposed by the simple elective attraction of bodies for its hydrogen.

The attraction of a body for hydrogen does not effect the decomposition of water, when assisted by an increase of repulsive motion, as the following experiment will prove.

EXPERIMENT XII.

One hundred and four cubic inches of water, previously boiled to expel the atmospheric air, were heated with three cubic inches of conferva fusca, in a vessel from which light was excluded. The temperature was gradually raised to 200°; but not more than a few globules of gas were formed, which by trial with nitrous gas proved to be of the same quality as atmospheric air.

Water exposed to the solar light in contact with the marine cryptogamiæ, or any organized hydrogen attractor, is decomposed by the force of two attractions; that of the hydrogen attractor for hydrogen, and of light for oxygen, as the following experiment will prove.

EXPERIMENT XIII.

Into a green glass globe containing 214 cubic inches of sea-water, previously boiled to expel the atmospheric air, one cubic inch of conferva littoralis was inserted. The globe was inserted in a jar of water of a similar kind, and exposed in a bright sunshine for four hours. In this time five cubic inches of gas were formed; which by trial with nitrous gas, proved to be $\frac{71}{100}$ parts phosoxygen, and $\frac{29}{100}$ azote.* The next day the globe was exposed to a bright sunshine for three hours. Two cubic inches, and five-tenths were produced, which by trial with nitrous gas, proved to be $\frac{76}{100}$ phosoxygen, and $\frac{24}{100}$ azote. The day after, the globe was exposed for five hours; but the sky was often clouded, and there fell some showers. Three cubic inches were formed, of the quality of $\frac{86}{100}$ phosoxygen and $\frac{14}{100}$ azote. After this, all the gas formed, contained from $\frac{76}{100}$ to $\frac{86}{100}$ of phosoxygen. The other gases liberated with the phosoxygen, appeared to be nitrogen and carbonic acid: at the latter part of the experiment, there was some indication of the presence of hydrogen.

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* By azote, I mean a gas incapable of diminution with nitrous gas; I have always called the gas to which the French nomenclators give the name of azote, nitrogen, after Chaptal, and some English chemists.

The whole quantity of gas produced from 214 cubic inches of water, in thirty-six hours of sunshine, was 46 cubic inches of the mean quality of $\frac{80}{100}$ phosoxygen, and $\frac{20}{100}$ of a gas or gases undiminishable by nitrous gas.

I have made a number of experiments on the decomposition of water and carbonic acid by the marine cryptogamiæ, &c. the particulars of which it is unnecessary to mention here. I shall give an account of them in an essay on the generation of phosoxygen. A few observations made in the course of these experiments, will, I think, afford additional proofs of the theory delivered in this essay; and therefore I shall relate them.

First, An increased or diminished temperature produced no sensible difference in the production of gas.

Secondly, A very strong artificial light acted similarly in the production of gas, to the solar light.

Thirdly, The capillary, dark, coloured, and opaque confervæ, generated more and better gas, than the white or pellucid. The confervæ generated more and better gas than the ulvæ, and the ulvæ more than the fuci.

Carbonic acid is not decomposable by light alone. No alteration is effected in it, though exposed for any length of time to the solar rays; nor is it decomposable by vegetables; which, as is evident from their analysis, attract carbon in large quantities. These facts I have proved by experiments, of which an account will be given in an essay on the generation of phosoxygen.

Carbonic acid is decomposable by the force of two attractions; that of any vegetable base, or carbon attractor for its carbon; and that of light, for its oxygen, as the following experiment will prove.

EXPERIMENT XIV.

A plant of Arenaria Tenuifolia planted in a pot filled with very dry earth, was inserted in carbonic acid, under mercury. The apparatus was exposed to the solar light, for four days successively, in the month of July. By this time the mercury had ascended considerably. The gas in the vessel was now measured. There was a deficiency of one-sixth of the whole quantity. After the carbonic acid was taken up by potash, the remaining quantity, equal to one-seventh of the whole, was phosoxygen almost pure. From this experiment, of which a further detail will be given in an essay on the generation of phosoxygen, it is evident that carbonic acid is decomposed by two attractions; that of the vegetable for carbon, and of light for oxygen: the carbon combines with the plant, and the light and oxygen combined are liberated in the form of phosoxygen.

Thus we have direct synthetical as well as analytical proofs of the composition of phosoxygen. It has been demonstrated then, *that phosoxygen is light combined with oxygen.*

I have heretofore possessed no balance sufficiently accurate to determine exactly the deficiency of weight from the light liberated in different combustive processes. It is probable that light is liberated in an imperceptible form in some combustions unaccompanied with great generation of repulsive motion. In these processes we can determine its liberation only from the deficiency of weight perceived.

It would probably throw much light upon the properties of the different oxyds and acids to determine the quantity of light entering into their composition.

The active properties of this substance may in a great measure influence the effects produced by the bodies into whose composition it enters on the organs of sense.

If it were possible to determine with accuracy the deficiency of weight in combustion arising from the liberated light, we might be able to discover the quantities entering into the composition of the acids.

Independent of the great use of phosoxygen, as the *pabulum vitæ* of organic beings, it is of the greatest importance to man simply considered as the supplier of light and heat by combustion. On the decomposition of phosoxygen by combustible bodies, the greater portion of the comforts and luxuries of life depends. Without combustion man might have wandered for ever barbarous and uncivilised in his native deserts. By the help of combustion the artist and manufacturer fabricate the tools, by which we erect cities, subdue and cultivate the earth, and directly derive our support. Assisted by combustion, Commerce erects the stately vessel, subjugates the ocean, showers plenty over every nation, and connects mankind together. By the arts, dependent on combustion, science and philosophy, no longer confined to thinking individuals, exist in characters. The press has made them immortal, and will ever continue to extend their beneficial influence. And lastly, aided by combustion, the sage devotes to philosophy the solitary hours of midnight, pursuing those combinations of ideas, which, producing inventions, improve and ameliorate the condition of man.

I am inclined to believe from some circumstances, observed in the course of these experiments, that light and oxygen combine in different proportions. This opinion at present I am not able to demonstrate experimentally; but I think it is countenanced by a number of facts. The phænomena observed in the higher regions of the atmosphere render this supposition extremely probable. Respiration is painful on the tops of high mountains, and an inflammatory state of the system is induced; combustion is carried on with greater facility and at a lower temperature than on the plain, as M. Saussure found that carbon caught fire sooner and burnt quicker on the top of the Alps than on the plain beneath. Fiery meteors appear at an amazing height in the atmosphere, much beyond that at which the solar rays are refracted:[*] and these meteors most probably arise from the formation of water. We cannot account for these phænomena on any common principles. Phosoxygen and Nitrogen are intimately combined here below; and they expand, when acted on by an increased repulsive motion in the same ratio. Now as the volumes of elastic fluids are in the inverse ratio of their compressing weight; if phosoxygen and nitrogen be supposed to compose the whole of our atmosphere, then must the quantity of phosoxygen in the atmosphere decrease in proportion as the height increases.

On this supposition the phænomena are totally inexplicable. For a deoxygenated [†] atmosphere, instead of generating an inflammatory state of the system, tends to diminish it; combustion is carried on with ease and rapidity in proportion as the quantity of phosoxygen is greater; and if the atmosphere at 90 miles high be supposed to be composed of eminently rarefied air, it is almost impossible that combustion could be carried on there. These difficulties can be got over with ease on the supposition, that light and oxygen combine in different proportions. Light, continually acting upon the phosoxygen of the atmosphere, may combine with portions of it, and form a luminated phosoxygen; which must necessarily be of less specific gravity, and easier of decomposition than phosoxygen; and this gas, from its small specific gravity, and probably still farther combinations with light, may extend to an amazing distance from our planet.

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[*] One of these was computed by Dr. Halley to be above ninety miles high.

[†] Nor will the substraction of pressure from the vessels account for this inflammatory state of the system, as action and reaction are equal.

The higher regions of the atmosphere being supposed to be filled with this gas, combustion must take place on the tops of mountains at a lower temperature than on the plain, and with a greater liberation of light; because the phosoxygen there is combined with a greater proportion of light. Respiration must become painful, and an inflammatory state of the system be induced; because the blood becomes supersaturated with light; which, as will be proved in the theory of respiration, is probably in a peculiar manner one cause of inflammation. The rays of light are not refracted in the atmosphere above 45 miles high, because beyond that the atmosphere is amazingly rare, being composed of phosoxygen highly luminated. Hydrogen ascends in the atmosphere, till it comes in contact with highly luminated phosoxygen probably of the same specific gravity: the oxygen loosely adhering to the light, is attracted from it by the hydrogen at the common temperature of the atmosphere to form water, whilst the light is liberated, and hence the phænomena of fiery meteors at a very great height. I have invented experiments for the investigation of this opinion; and I hope to be soon possessed of the means for their execution.

From the great quantity of light liberated in many combustive processes, particularly those in which the phosphoric, sulphuric, and carbonic acids and water are formed, we may fairly conclude that phosoxygen is wholly decomposed in these processes; the light liberated and the oxygen attracted by the base; yet there are others, as will be by-and-bye proved, in which there is only a partial decomposition of phosoxygen. In these only a portion of light is liberated, whilst the other part united to the oxygen combines with the attracting base. And phosoxygen (oxygen and light) often combines with bodies, without decomposition. These substances, which are now to be treated of, are combinations of light, oxygen and bases.*

We have been obliged to form a new nomenclature for the combinations of phosoxygen; neither that of the phlogistians, or of the calorists, would express their composition with accuracy. On the modern principles of chemical nomenclature all compound substances should be distinguished by names characteristic of the substances forming the compound. We have endeavoured to adhere to this plan. All the combinations of phosoxygen that have acid properties, are denoted by the names of phosacids; those which have no acid properties, are called phosoxyds. By these terms, the compounds of light, oxygen, and bases, will be sufficiently distinguished from the combinations of oxygen and bases which are simply called oxyds and acids.

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* From the experiments related by chemical writers on the metallic oxyds, one can draw no certain conclusions concerning the light liberated in oxydation. The peculiar properties of these bodies and their uses, have been more attended to than the process of oxydation.—I intend as soon as an opportunity offers to engage in a set of experiments on oxydation.

The terminations *ous* and *ic*, after the principles of the French nomenclators, will signify the different quantities of phosoxygen entering into the composition of the phosoxyds and phosacids. The names of the acidifiable and oxydable bases are nearly the same as in the French nomenclature. We have substituted nitrogen for azote, after Chaptal, Pearson, and some other chemists.

COMBINATIONS OF PHOSOXYGEN.

Substances that combine with Phosoxygen.	COMBINATIONS OF PHOSOXYGEN WITH SUBSTANCES.	
NEW AND OLD NAMES.	NEW NAMES.	OLD NAMES.
Nitrogen .	1 Nitrous Phosoxyd 2 Nitric Phosoxyd 3 Nitrous Phosacid 4 Nitric Phosacid	1 Gaseous Oxyd of Azote 2 Nitrous Gas 3 Nitrous Acid 4 Nitric Acid
Muriatic Acid	Muriatic Phosacid	Oxygenated Muriatic Acid
Platina . . .	Platinic Phosoxyd	Oxyd of Platina
Gold . . .	Auric Phosoxyd	Oxyd of Gold
Silver . . .	Argentic Phosoxyd	Oxyd of Silver
Mercury . .	Mercuric Phosoxyd	Red Oxyd of Mercury
Lead	Plumbic Phosoxyd	Red Oxyd of Lead
Tungsten . .	Tunstic Phosoxyd	Yellow Oxyd of Tungsten
Manganese . .	Manganesic Phosoxyd	Oxyd of Manganese
Chrome . .	Chromic Phosacid	Acid of Chrome *
Cobalt . . .	Cobaltic Phosoxyd	Rose-coloured Oxyd of Cobalt
Other Metals.	Quere	Quere

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* This Acid has been lately discovered by Vauquelin in the red lead of Siberia.

COMBINATIONS OF THE NITROUS AND NITRIC PHOSACIDS WITH SUBSTANCES.

Substances that combine with the Nitrous and Nitric Phosacids.	COMBINATIONS OF THE NITROUS AND NITRIC PHOSACIDS WITH SUBSTANCES.	
NEW AND OLD NAMES.	NEW NAMES.	OLD NAMES.
Barytes. .	Phosnitrite Phosnitrate } of Barytes	Nitrite Nitrate } of Barytes
Strontian. .	Phosnitrite Phosnitrate } of Strontian	Nitrite Nitrate } of Strontian
Potash . .	Phosnitrite Phosnitrate } of Potash	Nitrite Nitrate } of Potasha
Soda . . .	Phosnitrite Phosnitrate } of Soda	Nitrite Nitrate } of Soda
Lime . .	Phosnitrite Phosnitrate } of Lime	Nitrite Nitrate } of Lime
Magnesia. .	Phosnitrite Phosnitrate } of Magnesia	Nitrite Nitrate } of Magnesia
Ammonia .	Phosnitrite Phosnitrate } of Ammonia	Nitrite Nitrate } of Ammonia
Argilla . .	Phosnitrite Phosnitrate } of Argilla	Nitrite Nitrate } of Argilla
Metallic Oxyds and Phosoxyds	Phosnitrites Phosnitrates } of Metals	Nitrite Nitrate } of Metals

COMBINATIONS OF PHOSOXYGEN.

COMBINATIONS OF NITROGEN WITH PHOSOXYGEN.

NITROGEN forms seventy-two hundred parts of the air of our atmosphere. With regard to the present state of our knowledge it must be considered as an undecompounded substance.

It enters into combination with a number of bodies. In organic compounds it is found in considerable quantities; and appears to act an important part in the phænomena of life. Phosoxygen and nitrogen combine in different proportions, and form substances possessing specifically different properties.

When phosoxygen and nitrogen are made to combine by the action of the electric spark, it appears that no light is liberated in the process. In this experiment nitric phosacid is formed. And as phosoxygen is compounded of light and oxygen, and nitrogen is a simple substance, it is evident from this experiment that nitric-phosacid is a compound of light, oxygen and nitrogen. The proof from analytical experiment is even more conclusive, and will account for a phænomenon which the other theories were inadequate to explain.

EXPERIMENT XV.

Phosnitrate of potash mingled with half its weight of carbon was fired by a burning-glass in the exhausted receiver. The conflagration took place, and a considerable quantity of light was liberated in the repulsive projectile state. The gaseous products were examined and proved to be nitrogen and carbonic acid. The fixed substance remaining after combustion was potash mingled with carbon. The quantities of the products were not accurately ascertained, as the end of this experiment was simply to determine their nature.

Nitric phosacid then is compounded of light, oxygen and nitrogen. From the experiments of Lavoisier we may conclude, that one hundred parts of it contain seventy-nine and a half of phosoxygen, and twenty and a half of nitrogen. When carbon heated to a certain degree is placed in contact with phosnitrate of potash it attracts the oxygen of the nitric phosacid, and combines with it to form carbonic acid: the light and nitrogen having no combining attraction for each other, or for potash, are liberated, one in the repulsive projectile and the other in the gaseous form. The great increase of repulsive motion is produced from the rapid divellent and combining chemical motions generated in the process. The detonation is occasioned by the undulatory motion generated in the circumambient atmosphere by the rapid dislodgment of a body of air equal in bulk to the elastic fluids generated in the process.*

The nitric phosacid is decomposable by increased repulsive motion alone, into nitrogen and phosoxygen.

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* Lavoisier, and the Calorists, suppose this detonation to be occasioned in a great measure by the liberation of caloric. They assert that when oxygen gas and azotic gas combine to form nitric acid, they retain in their composition a great quantity of the caloric which rendered them gaseous. This caloric they say is liberated in the decomposition of nitrate of potash, and hence, the increase of temperature, detonation, &c. This hypothesis is one of the most absurd advanced by the Calorists.—On their theory of caloric, it is evident, that when the temperatures of bodies are increased in chemical processes, their capacities must be diminished; and therefore, the capacities of carbonic acid, azote and

It combines with water, with the alkalies, the alkaline earths and metallic oxyds, forming compounds formerly called nitrates; but which to express their composition more accurately, we have called phosnitrates.

When nitric phosacid is exposed to light, it loses a portion of its oxygen and light, and becomes nitrous phosacid, as was before observed. One hundred parts of this acid appears to contain about seventy-four parts phosoxygen, and twenty-six nitrogen. Like the nitric phosacid it is decomposable by increased repulsive motion into phosoxygen and nitrogen; and when combined with bases, by certain heated oxygen attractors, into light, oxygen and nitrogen. The nitrous phosacid combines with water, with the alkalies, alkaline earths, metallic oxyds, &c. With the alkalies, alkaline earths, and metallic oxyds, it forms compounds which possess, like the phosnitrates, the property of detonating, i. e. of being rapidly decomposed by heated oxygen attractors; to these substances we have given the names of phosnitrites.

When a considerable portion of oxygen and light is subtracted from the nitric phosacid by metallic substances, the gas liberated during the process is nitric phosoxyd.

This substance combines in small proportions with water, is a permanent gas at the common temperature of the atmosphere, and appears to contain about sixty-eight per cent phosoxygen, and thirty-two nitrogen. Phosphorus decomposes it by attracting the oxygen to

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potash, must be much less than those of carbon and nitrate of potash, than which nothing is more false: for I have found by experiment, that the united capacity of nitrate of potash and carbon, is much less than that of carbonic acid or azote, and independent of this, they have totally neglected the liberated light.

form phosphoric acid, whilst the light and nitrogen are liberated.

Dr. Priestley discovered, that when nitric phosoxyd (nitrous air) is exposed to the action of moistened iron filings for a certain time, a diminution of its volume takes place, and a gas is formed, possessing peculiar properties, capable of supporting the flame of a candle better than atmospheric air; but at the same time totally unfit for the respiration of animals. To this gas he gave the name of dephlogisticated nitrous air; but we have called it from its composition, nitrous phosoxyd. It appears to contain less oxygen, and a larger proportional quantity of light than nitric phosoxyd, as will appear from the following observations:

OBSERVATION *g*.

When nitric phosoxyd is exposed to the action of heated iron for a certain time, the iron becomes oxydated, and nitrous phosoxyd is formed. No light is liberated during the process. The oxyd of iron formed in this manner, is in every respect similar to that formed by direct decomposition of phosoxygen.

OBSERVATION *h*.

When the repulsive motion of phosnitrate of ammonia is increased to a certain degree, a new arrangement of its principles takes place. Water and nitrous phosoxyd are formed, and a portion of azote is liberated. No luminous appearance is perceived during this process.*

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* [In a letter addressed to Mr. Nicholson of the 11th of April 1799, he states, that when the above experiment is made under favourable circumstances, light is emitted. In his first experiment, the salt was

Now as nitric phosoxyd and nitric phosacid are compounded of light, oxygen, and nitrogen, and according to the foregoing observations, no light is liberated during the formation of nitrous phosoxyd, it is evident, that it must be composed of nitrogen, light, and a smaller portion of oxygen. The Dutch chemists have concluded from experiments on its decomposition, that one hundred parts of it contain thirty-seven and half oxygen, and sixty-two and half nitrogen. The light entering into its composition, has never been attended to by any chemist. This gas combines in very small proportions with water, and appears to possess no acid properties. It is decomposable by hydrogen and by certain combinations of hydrogen and carbon. Sulphur, phosphorus and carbon, appear incapable of attracting oxygen from it at any common temperature. I have found by experiment, that a candle burns in this gas with a flame larger and more brilliant than in a gas composed of a mixture of thirty-eight parts phosoxygen, and sixty-two nitrogen; which alone would prove that it contained a larger proportional quantity of light, than any of the other combinations of nitrogen and phosoxygen. I have made some other experiments on the composition of this gas, and some on the effects produced by it on animals, which will be detailed in a distinct essay.*

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exposed to heat mixed with a large quantity of siliceous sand; in the later experiment it was mixed with a small quantity only, and quickly heated.—Nicholson's Journal, 4to. vol. iii. p. 55.]

* [At this time he had not attempted to breathe it pure; he discovered that it was respirable on the 17th of April 1799. In a letter to Mr. Nicholson of this date, he thus announces the discovery: "I have this day made a discovery, which, if you please, you may announce in your Physical Journal, namely, that the nitrous phosoxyd, or gaseous oxyd of azote, is respirable when perfectly freed from nitrous gas. It appears

It is extremely probable that the air of our atmosphere is a chemical combination of phosoxygen and nitrogen. A mixture of twenty-eight parts of phosoxygen, and seventy-two of nitrogen, is not exactly similar to the air of our atmosphere. We want, however, experiments to determine the truth or falsehood of this supposition. If the fact was proved, this gas might be called phosoxyd of nitrogen.

COMBINATIONS OF THE MURIATIC PHOSACID (OXYGENATED MURIATIC ACID.)

Substances that combine with Muriatic Phosacid.	COMBINATIONS OF THE MURIATIC PHOSACID WITH SUBSTANCES.	
NEW AND OLD NAMES.	NEW NAMES.	OLD NAMES.
Barytes	Phosmuriate of Barytes	Oxygenated Muriate of Barytes
Strontian ..	Phosmuriate of Strontian	Oxygenated Muriate of Strontian
Potash	Phosmuriate of Potash	Oxygenated Muriate of Potash
Soda	Phosmuriate of Soda	Oxygenated Muriate of Soda
Ammonia ..	Phosmuriate of Ammonia	Oxygenated Muriate of Ammonia*
Lime	Phosmuriate of Lime	Oxygenated Muriate of Lime
Magnesia ..	Phosmuriate of Magnesia	Oxygenated Muriate of Magnesia
Argilla	Phosmuriate of Argilla	Oxygenated Muriate of Argilla
Metallic Oxyds and Phosoxyds	Phosmuriates of Metals	Oxygenated Muriates of Metals

* Quere?

to support life longer than common air, and produces effects which I have no time to detail at present. Dr. Mitchell's theory of contagion is of course completely overturned."—Nicholson's Journal, 4to. vol.iii. p.93.]

OF THE MURIATIC PHOSACID.

The muriatic acid has been long discovered. Analogy would induce us to suppose that it is a compound of oxygen with some acidifiable base; but we are at present possessed of no facts sufficient to prove its composition. We have attempted to decompose this acid by passing phosphoric vapour through muriate of lime strongly heated; but no phosphoric acid was formed, and the muriate of lime remained unaltered. The muriatic acid combines with phosoxygen, and forms an acid possessing peculiar properties. To this acid discovered by Scheele, the French nomenclators have given the name of oxygenated muriatic acid, on the supposition that it was muriatic acid combined with oxygen. We have called it muriatic phosacid, to express the combination of Light, Oxygen, and Muriatic Acid. The following experiment will prove analytically that the muriatic phosacid is a compound of light, oxygen, and muriatic acid.

Experiment XVI.

Phosmuriate of potash was mingled with twice its weight of carbon, and fired by a burning glass in the exhausted receiver. The detonation took place with great increase of temperature in the surrounding bodies. A great quantity of brilliant repulsive projectile light was liberated. The gaseous products, on examination, proved to be carbonic acid and muriatic acid, the fixed substances remaining after combustion, were carbon, potash, and a small quantity of muriate of potash.

From this experiment it is evident that the muriatic phosacid is compounded of light, oxygen, and muriatic acid. Phosmuriate of potash is compounded of phosmuriatic acid and potash. When carbon is placed in contact with this substance, and heated, it attracts the oxygen of the muriatic phosacid stronger than it is attracted by the light and muriatic acid, and combines with it to form carbonic acid. The light and muriatic acid having no affinity for each other, are liberated. The great increase of repulsive motion generated in this process arises from the rapid motions of the combining and liberated bodies.

The composition of the muriatic phosacid may be proved by synthesis, as well as analysis; for muriatic acid is never phosoxygenated, but by combining with phosoxygen, or by attracting it from some of its combinations, as will be better understood hereafter.

The muriatic phosacid is decomposable by light, as was proved by Observation *b*. It is likewise decomposable by phosphorus, sulphur, carbon, and metallic substances, when their temperatures are slightly increased by friction or percussion.*

The muriatic phosacid combines with potash, soda, the alkaline earths, metallic oxyds, phosoxyds, &c. The phosmuriate of potash appears to contain in its composition a still larger quantity of oxygen and light than the muriatic phosacid; for during the combination of the muriatic phosacid with potash, a certain quantity of muriatic acid is found in combination with a portion of the potash. And when sulphuric acid is poured on phosmuriate of potash, light, phosoxygen, and phosmuriatic acid gas are liberated.* The phosmuriate of soda possesses similar properties to the phosmuriate of potash, with greater solubility in water. The other combinations of the phosmuriatic acid have not heretofore been much attended to. Berthollet found that it was incapable of combination with ammonia at the common temperature; when mingled with this substance, a double decomposition takes place, and water, muriatic acid, and nitrogen, are the products. We have succeeded in combining this acid with strontian.† The phosmuriate of strontian possesses extreme solubility; its crystallization is similar to that of the muriate of strontian, and like that salt, when dissolved in alcohol, it communicates to it the property of burning with a rose coloured flame. It detonates slightly with carbon and phosphorus. During the decomposition of this salt by the sulphuric acid, a beautiful phænomenon takes place, the liberation of variously coloured light.

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* To account for these detonations, the French chemists were obliged (as in the case of the nitric phosacid) to suppose an immense quantity of caloric in the composition of this acid, which is directly contradictory to Black's doctrine of capacity.

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* We thought it probable, from the phænomenon accompanying the decomposition of the phosmuriate of strontian, about to be described, that the same effects would be produced when the phosmuriate of potash was used. Sulphuric acid, of the specific gravity of 1·85, was poured on a few grains of phosmuriate of potash: vivid white light was instantly liberated, and phosoxygen and phosmuriatic acid gas given out with great rapidity.

† I effected this combination by passing muriatic phosacid gas through a saturated solution of strontian-lime heated above 200°. The strontian lime was obtained by my friend Mr. Clayfield, from the sulphate of strontian discovered by him near Bristol. We first attempted the combination by passing muriatic phosacid gas through strontian-lime water at the temperature of 30°—40°; but without success. Mr. Clayfield proposed to try the effect of cold. The temperature of the solution was lowered by snow and salt to 10°, and the gas passed through; but no considerable combination was effected. We then dissolved as much earth as possible in boiling water, and passed the gas through the saturated solution. The combination immediately took place. The solution of phosmuriate of strontian was of a dusky orange colour. We had some difficulty in obtaining the crystals of this salt, from its extreme solubility. By gentle evaporation and cooling, it gave fine needle-formed crystals. These crystals slightly detonated with phosphorus and charcoal. Alcohol holding them in solution, burnt with a rose coloured flame. When sulphuric acid was poured into a solution of

It is not improbable that by attending to the combinations of the muriatic phosacid, we may discover some cheap substitute for the phosnitrate of potash. From the present consumption of this substance in the murder of mankind, the nitric phosacid is an extremely expensive article. The great importance of this acid in chemistry and the arts, renders the cheaper acquisition of it a great desideratum.*

this salt in water, with a design to prove its composition by analysis, a beautiful and unexpected phænomenon took place. The room was accidentally darkened at the moment that this experiment was made, so that we were enabled to perceive a vivid luminous appearance whilst muriatic phosacid gas was liberated with great increase of temperature. We repeated the experiment two or three times with the same result, except that the light was differently coloured. When sulphuric acid of the specific gravity of 1·85 was poured on the dry salt, no light was liberated, and the decomposition went on very slowly; on the addition of water, the effects before described again took place. This experiment, independent of its beauty, is extremely pleasing, as affording an instance of a true combustion, that is, the production of light and heat, by the mixture of two incombustible bodies.

* [In a letter to Mr. Nicholson already quoted, he states, "With the hopes of discovering a cheap substitute for nitre, I have lately made the phosmuriates (oxygenated muriates) of strontian and barytes. The properties of the first correspond with the account I have given of them (as in the text) except that its solubility is not so great as I at first suspected. The phosmuriate of barytes crystallizes in plates, and detonates very slightly with charcoal and phosphorus. A solution of it in water, like that of the phosmuriate of strontian, becomes luminous when the sulphuric acid is poured into it."]

COMBINATIONS OF LIGHT, OXYGEN, AND METALLIC SUBSTANCES.

SINCE the discovery of oxydation by the great Lavoisier, chemical philosophers in general have considered the process as the simple decomposition of oxygen gas (oxygen and caloric); the combination of oxygen with the oxydable base, and the liberation of caloric. All metallic oxydations have been conceived to be similar, and differing only in the rapidity of the decomposition of oxygen gas. As light has been little attended to, even among the chemical principles of the most celebrated pneumatists, we are not surprised to find that it has been neglected in the process of oxydation. The combinations of light, oxygen, and metallic bodies, have not been heretofore distinguished from the simple combinations of oxygen with these substances, though from the differences of their properties alone they might well be considered as a distinct class of substances. To these bodies we have given the name of phosoxyds, to distinguish them from the simple combinations of oxygen, and to express their composition with accuracy.

PLATINIC PHOSOXYD.

Platina appears incapable of directly combining with light and oxygen at any known temperature. This combination is effected by the decomposition of the muriatic phosacid, or the murionitric phosacid. In the decomposition of the muriatic phosacid by platina, the platina combines with the light and oxygen, so as to convert the acid into muriatic acid. The properties of this phosoxyd are but little known, and I have never had an opportunity of examining them.

AURIC PHOSOXYD.

Gold, which is incapable of decomposing, or of directly combining with, phosoxygen at any known temperature, possesses the power of attracting it from some of its combinations. Gold becomes phosoxydated by attracting light and oxygen from the muriatic phosacid or the murionitric phosacid; it is extremely probable, from the properties of this phosoxyd, that it contains a larger proportion of oxygen, and a smaller proportion of light, than the other phosoxyds. Exposed to light, it gives out phosoxygen and the metal is revivified. It combines with the acids, and with ammonia; with ammonia it forms the compound called fulminating gold, but which might be called with greater propriety, auric phosoxyd of ammonia. From the decomposition of this substance alone, we might prove that light was one of the constituent parts of auric phosoxyd. When the temperature of auric phosoxyd of ammonia is increased a little, it is decomposed with a great explosion, and the products are light, nitrogen, and water. In this process the hydrogen of the ammonia combines with the oxygen of the auric phosoxyd to form water, and the nitrogen of the ammonia, and the light of the phosoxyd, having no attraction for each other or for water, are liberated.

ARGENTIC PHOSOXYD.

Silver, like gold and platina, is incapable of combining with phosoxygen directly, at any known temperature. Silver appears capable of combining with oxygen, as well as phosoxygen, and consequently it decomposes both the acids and phosacids. It attracts oxygen and light from the nitric phosacid with great rapidity, and becomes phosoxydated, whilst the remaining light and oxygen of the acid fly off with the nitrogen in the form of nitric phosoxyd. The argentic phosoxyd combines with the acids, and with ammonia. Its combination with ammonia affords one of the most astonishing phænomena in chemistry. To form this substance, the phosoxyd of silver must be precipitated from its solution in nitric phosacid by lime-water. This precipitate after exposure to light for some hours, must be stirred in a solution of ammonia. When this solution is evaporated, the crystallised substance remaining is the fulminating silver, or argentic phosoxyd of ammonia. The slightest possible change of temperature by friction, percussion, or any other means, causes this substance to explode with an astonishing detonation, and the liberation of light. The products of this detonation have never been examined. Light we know is one of them, the others are probably water and nitrogen: for the substance is a compound of light, oxygen, silver, nitrogen, and hydrogen. The slightest change of temperature disposes the light to fly off, and the hydrogen and oxygen to combine to form water. The great increase of temperature and the detonation inexplicable on the former theories, are accounted for with the greatest ease on the theory of repulsive motion, without any absurd or unnatural suppositions.

MERCURIC PHOSOXYD.

Mercury combines directly with phosoxygen, as appears from the following observations.

OBSERVATION *i.*

When mercury is placed in contact with phosoxygen, and its temperature raised nearly to its boiling point, the phosoxygen and mercury are gradually converted into a red substance possessing properties essentially different from mercury or phosoxygen. No light is liberated in this process. The phosoxyd of mercury is consequently a combination of light, oxygen, and mercury. This substance is likewise formed by the decomposition of the nitric phosacid. Its fine red colour, like that of most other substances, appears to depend on the light entering into its composition. It combines with the acids, and with ammonia. With ammonia it forms a fulminating compound, the mercuric phosoxyd of ammonia.

The mercuric phosoxyd is decomposable by light and increased repulsive motion, into phosoxygen and mercury.

PLUMBIC PHOSOXYD.

The plumbic phosoxyd (red oxyd of lead) evidently contains oxygen and light; for when the white oxyd of lead is heated in contact with phosoxygen, it becomes red and more ponderous, and the phosoxygen is absorbed without the liberation of light. When muriatic acid is distilled from the plumbic phosoxyd, it becomes muriatic phosacid. From whence we may conclude that the plumbic phosoxyd is compounded of oxygen, light, and lead.

Tungstic Phosoxyd.

The tungstic phosoxyd (yellow oxyd of tungsten) appears to contain light in its composition. It gives out phosoxygen, and becomes blue on exposure to the solar light. It appears capable of combining with the alkalies, alkaline earths, &c.

Manganesic Phosoxyd.

The manganesic phosoxyd (black oxyd of manganese) evidently contains phosoxygen; it affords it on the application of heat. When muriatic acid is distilled from it (the manganesic phosoxyd), it becomes muriatic phosacid, that is, it subtracts a portion of light and oxygen from the manganesic phosoxyd.

Chromic Phosacid.

This acid, just discovered by the ingenious Vauquelin, appears to contain light; its red colour alone would induce us to believe this, and from the experiments of Vauquelin, it appears that it loses its red colour when exposed to light, and most probably gives out a portion of light and oxygen.

Cobaltic Phosoxyd.

The cobaltic phosoxyd is formed by the decomposition of the nitric phosacid.

We have found that it gives out phosoxygen when its repulsive motion is increased, from whence we conclude that it is a combination of light, oxygen, and cobalt.

The phosoxyds possessed of the most striking properties are, the auric, argentic, mercuric, and plumbic. The facility with which these bodies are decomposed, is evidently dependent on the light entering into their composition. Indeed we have no single instance of a chemical detonation independent of the presence of light. The ease with which the equilibrium of the principles of the phosoxyds of ammonia is destroyed, depends on the ease with which light takes its repulsive projectile form. We are in want of a set of accurate experiments on the process of oxydation and phosoxydation. It is probable that many metals, besides those we have mentioned, are capable of combining with phosoxygen. The different colours and properties of the different oxyds of the same metal may probably depend on certain quantities of light and oxygen entering into their composition.

Such then are the inorganic combinations of light. From the discovery of them we are enabled to explain the phænomena of combustion, detonation, &c. They open to us an extensive field for experimental investigation. It is probable that we shall detect light in many other substances, in which it has not been hitherto suspected. That extensive class of substances which has been heretofore distinguished by the common name of oxygen-attracting, must be divided into distinct classes, from the differences of the attractions of the substances composing it. Some of these substances, as phosphorus, sulphur, &c. are simple attractors of oxygen, that is, decomposers of phosoxygen. Others, as iron, zinc, copper, &c. under different circumstances, appear to attract oxygen and portions of light with oxygen. Another class combines with phosoxygen, or light and oxygen, without decomposition, as nitrogen, muriatic acid, mercury, &c.

We perceive a correspondence between the quantities of light and oxygen entering into the composition of bodies, and their colours. By attending to this circumstance, and by determining the quantities of light liberated in oxydation, and comparing the properties of the oxyds, phosoxyds, &c. we may make some discoveries in an important branch of corpuscular philosophy hitherto unknown,—the causes of the differences of the capabilities of bodies for receiving the communicated repulsive motion of light, that is, the causes of the differences of their colours.

RECAPITULATION.

This recapitulation is designed to present the theory founded upon the experiments described, in a short view capable of being at once considered by the mind.

1st. Matter is supposed to be endowed with the active properties of repulsive motion and attraction. By the terms repulsive motion and attraction, we simply mean to express the causes of certain effects which are uniformly and constantly produced. In denying the existence of caloric, we do not assert that there does not exist a number of substances which are totally incognisable by our senses; but we consider all matter as governed by the same laws, and as active properties must be ascribed to some matter, and as we perceive the effects of them in that matter with which we are acquainted, we have a right to conclude that they belong to it. Nothing is more unphilosophic than to imagine beings for the sake of attributing to them active powers, when our sensations inform us of the existence of bodies to which they belong.

2. The most subtile etherial fluids with which we are acquainted, are governed by the laws of attraction and repulsive motion. Amongst these is light, which acts the most important part in the economy of the universe. This substance is subject to the common laws of matter, and requires no principles, but attraction and repulsive motion, to account for its appearances and changes.

3. It enters into combination with bodies. In the phosphorescent bodies it exists in a state of loose combination.

In phosoxygen it is intimately combined with oxygen.

4. From the decomposition of phosoxygen by bodies that attract oxygen, the phænomena of combustion are explained.

5. Phosoxygen combines with substances without decomposition.

These substances are nitrogen, muriatic acid, and certain metals. On the combination of phosoxygen with these bodies, the phænomena of detonation, &c. depend.

Light enters into the composition of living bodies. To understand these combinations is of infinite importance to man. On the existence of this principle in organic compounds, perception, thought, and happiness, appear to depend. We shall proceed to investigate the theory of respiration.

THEORY OF RESPIRATION.

THE dependence of life on respiration has always rendered it an important subject of consideration to physiologists; but till the discovery of pneumatic chemistry, no rational theory was advanced. It is foreign to our present design to consider all the different theories that have been formed. The theory of respiration now generally received by physiologists, is that advanced by Godwyn, Girtanner, &c. These philosophers assume oxygen gas to be oxygen combined with caloric; and since it is found by experiment that the oxygen gas made use of in respiration is diminished, and carbonic acid and water formed, it is asserted that oxygen gas is decomposed in the lungs. It is said, that one portion of the oxygen combines with the oxydable and acidifiable bases in the venous blood, and particularly with the iron; and that from this oxydation arises the vermilion colour of the arterial blood: another portion combines with the carbon of the blood and of the pulmonary mucus, to form the carbonic acid liberated in respiration; another portion combines with the hydrogen of the blood, to form the water liberated in respiration: the caloric combined with the oxygen partly combines with the blood, now increased in capacity, and is partly liberated, with the carbonic acid and aqueous gas. Without considering my experiments, or the theory of these papers, which directly overturn this hypothesis, there are the following objections to it.

1. Iron, which is generally assumed to be the reddening principle of the blood, never decomposes phosoxygen at so low a temperature as 98°, the greatest heat of the lungs, and phosoxygen is never decomposed by iron without rapid combustion, flame, and great heat.

2. Oxygen gas is never decomposed by carbon at so low a temperature as 98°, and is never decomposed without combustion, &c.

3. There is never a decomposition of phosoxygen by hydrogen at so low a temperature, and it is well known that this process does not take place without flame.

This theory of respiration, then, is evidently false. It will appear from the following experiments and observations:

1. That phosoxygen (light and oxygen) is not decomposed in the lungs.

2. That phosoxygen (light and oxygen) combines with the venous blood in the lungs.

3. That carbonic acid and water are both liberated from the lungs during this process, either by the increase of temperature, or from the superior affinity of phosoxygen for the venous blood.

Experiment XVII.

A phial containing twelve cubic inches and a half, was filled with very pure phosoxygen. The medial vein of a healthy man was opened, and the stream of blood directed into the phial. The mouth of the phial was immediately brought in contact with the arm, so as to entirely exclude all external air. The room was then darkened. As the blood flowed in, it changed from a dark red to a bright vermilion colour. When the phial was half full it was closed, and plunged in mercury heated to 90°. After remaining in this situation for half an hour, it was examined. The blood had coagulated, and was of a bright vermilion; some drops of water were formed on the sides of the phial. When the cork was drawn, about two cubic inches of mercury rushed into the phial, from whence I concluded that an absorption of gas had taken place. The gas remaining in the phial was examined. It proved to be three cubic inches and one-tenth of phosoxygen, mingled with nine-tenths of a cubic inch of carbonic acid.

During this experiment no light was liberated; it is consequently reasonable to suppose that there was no decomposition of phosoxygen; and as a considerable diminution of phosoxygen took place, and the blood acquired new properties, we may conclude that phosoxygen is capable of combination with the venous blood. To prove this by analysis as well as synthesis, I made the following experiment.

EXPERIMENT XVIII.

A phial containing about twelve cubic inches, having a pneumatic apparatus affixed to it, was filled with arterial blood from the carotid artery of a calf. The phial was placed in a sand bath of the temperature of 96°, and the heat gradually and slowly raised. In about ten minutes the temperature of the bath was 108°, and the blood began to coagulate. At this moment some globules of gas were perceived passing through the tube. Gas continued to pass in very small quantities for about half an hour, when the temperature of the sand was about 200°; the blood had coagulated perfectly, and was now almost black: about a cubic inch and eight-tenths of gas were collected in the mercurial apparatus; of this one cubic inch and one-tenth was carbonic acid, and the remaining seven-tenths phosoxygen.*

From this experiment it is evident that the arterial blood contains phosoxygen, and we have proved before by synthesis, that it is capable of combining with it directly. We are possessed of a number of experiments, which prove that phosoxygen is consumed in respiration. It has been likewise proved that gases can penetrate through moist membranes like those of which the vessels in the lungs are composed. We may therefore conclude that phosoxygen combines with the venous blood of the system in the pulmonary vessels. As no light was liberated in Experiment XVII. it is evident that there cannot be even a partial decomposition of phosoxygen in respiration, and, consequently, the carbonic acid and aqueous gas liberated cannot arise from the decomposition of phosoxygen by the carbon and hydrogen of the venous blood. It is then evident that they must be liberated from the venous blood. To prove this more clearly, I made the following experiment.

EXPERIMENT XIX.

I filled a small sheep's bladder with blood from the medial vein of an healthy woman. This blood never came in contact with any air during the experiment.

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* Great caution is requisite in making this experiment. If the temperature is not gradually and slowly increased, the liberated gases are carbonic acid and hydrogen. The first time that I made this experiment, raising the temperature too quickly, I obtained only these products. At a high temperature, the phosoxygen of the blood most probably combines with nitrogen, to form nitric phosacid.

The bladder was inserted in a vessel of water heated to 112°, and the gaseous products received by a pneumatic apparatus. They were carbonic acid and aqueous gas.

Respiration, then, is a chemical process, the combination of phosoxygen with the venous blood in the lungs, and the liberation of carbonic acid and aqueous gas from it. From the combination and decomposition, arises an increase of repulsive motion, which combined with that produced by the other chemical processes taking place in the system, and that generated by the reciprocal action of the solids and fluids, is the cause of animal heat; a heat which in the other systems has been supposed to arise chiefly from the decomposition of oxygen gas (oxygen and caloric).

Such then is the human respiration; and we are certain not only from analogy, but from experiments, that the breathing process of quadrupeds and birds is similar. Phosoxygen (oxygen and light) combines with the venous blood in their lungs.

As fishes exist in a different element; and as it has been supposed that they decompose both water and oxygen gas,* I endeavoured to ascertain by the following experiments the laws of their respiration.

EXPERIMENT XX.

I expelled by long boiling the atmospheric air from 64 cubic inches of sea water. This by means of mercury I entirely excluded from the contact of air. A small mullet was put into it, which instantly appeared much convulsed, and died in a few minutes.

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* Darwin's Zoonomia, vol. i. p. 472. Oxygenation of the Blood.

EXPERIMENT XXI.

A quantity of water was freed from atmospheric air by boiling. Two receivers, each of the capacity of 36 cubic inches, were filled with this water. Into one of these, two cubic inches of nitrogen were inserted, into the other, two of phosoxygen. By long and constant agitation, the gases were dissolved by the water, which was excluded from the contact of air by mercury. Into each of the receivers two minnows were inserted. Those in the water holding nitrogen in solution, died in about four minutes; those in the water holding phosoxygen in solution, appeared totally uninjured, and when examined after some hours, were still alive and healthy.

EXPERIMENT XXII.

The same receivers which I used in my last experiment, were filled with distilled water, freed from atmospheric air by a second boiling. Into each of these, three cubic inches of phosoxygen were inserted. The receivers were then agitated for some time, till the water in each of them had dissolved an equal quantity of gas; they were then inverted in a trough of mercury, so as to exclude atmospheric air from them. Four minnows were then conveyed into one of them through mercury. The receivers were now suffered to remain untouched for six hours, when they were examined. The minnows were alive, and no gas remained in the top of the receiver in which they had respired. The gas in the top of the other receiver remained nearly the same as at the commencement of the experiment. A quantity of lime-water was poured into each of these receivers; in that in which the fish had existed there was a very perceptible cloudiness, occasioned, as I suppose, by the formation of carbonate of lime; in the other there was no perceptible change.

From these experiments I conclude that the venous blood in the gills of fishes is phosoxydated by the phosoxygen held in solution by water; and that carbonic acid, and probably water, are given out as excrementitious by the venous blood in their gills. We have no reasons for supposing that fish decompose water, as we cannot discover that any hydrogen is formed by them in respiration.*

Light and oxygen then, (phosoxygen) are essential to life.

The perceptive and volitive powers depend for their continued existence on the constant supply of a certain quantity of phosoxydated blood to the nervous and muscular systems.

Perception more immediately depends on the continued supply of a certain quantity of arterial blood to the brain. In the brain and nervous system, some important change essential to life must be effected by it. As there is a necessity for a constant supply of phosoxygen to support the vital functions, there must be a constant expenditure of it in the performance of these functions. The medullary substance of the brain and nerves appears to possess the property of sensibility. This property is perfectly distinct from the irritability or contractile power of the muscular fibre. The nerves depend for their sensibility on their connection with the brain. In the brain all the sensations conveyed by the different nerves centre; and in the brain their correspondent ideas are associated together according to certain laws. The moment that the connection of a nerve with the brain is destroyed, it ceases to be sensible; and thought and action cease the moment that a supply of phosoxydated blood is cut off from the brain.

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* I have discovered by similar experiments that the zoophyta are governed by similar laws: that they, like fish, absorb the phosoxygen held in solution by water, as well as portions of nitrogen; and thus in their chemical attractions, as well as in their organic powers, seem to be the connecting links between vegetables and animals.

May we not venture to reason on the important and constant change effected in the brain and nerves by the phosoxydated blood? Is it not probable that the existence of some fine etherial principle in the brain and nerves is the immediate cause of sensible or perceptive action? If such a fluid exists, it must be continually supplied by the arterial blood, and constantly expended in sensible action. We have proved the existence of light in the arterial blood, and we have likewise proved its existence in different states. Is it then improbable to suppose that LIGHT is attracted or secreted from the blood by the brain in the form of an etherial fluid or gas, and perpetually conveyed by the brain to the nerves?*

A number of philosophers, simply from the identity of the action of the electric fluid, and the nervous influence on the irritable fibre, have concluded them to be the same, that is, have concluded the nervous fluid to be the electric aura.

We have before supposed the electric fluid to be condensed light. Thus we have another cogent reason for supposing that the nervous spirit is light in an etherial gaseous form.

On this supposition, sensations and ideas will be motions of the nervous ether or light exciting the medullary substance of the nerves and brain into sensitive action. The capability of the nerves to be excited into sensitive action by the motions of the nervous ether, must depend upon a peculiar constitution or organization of them; and the nerves during sensitive action must suffer some change, some loss of principles, and the equilibrium of their principles must be again supplied by the arterial blood.

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* [A modification of this hypothesis was revived by the author in his "Consolations in Travel," in the Dialogue entitled "The Proteus, or Immortality," and recent experiments on the blood and respiration are rather in favour of it.]

The irritability of the muscles, as well as the sensibility of the nerves, appears to depend on the continued supply of a certain quantity of arterial blood. Their irritability is not nearly so soon destroyed as the sensibility of the nerves. The fibre remains irritable for a considerable time after it is deprived of arterial blood. The muscles are most probably phosoxydated compounds, of which the numerous principles are in exact and delicate equilibrium; and it is likely that on this equilibrium their irritability depends. Any communicated impulse capable of producing increase of repulsive motion sufficient to occasion a new arrangement of principles in any part of the fibre, will produce irritable action. The impulses of certain external bodies, and the nervous motions, both appear equally capable of exciting the irritable fibre into action.

The chief principles* of the fibre appear to be nitrogen, hydrogen, carbon, oxygen, and light.† The immediate cause of irritable action is probably the combination of oxygen with the hydrogen and carbon, to form water and carbonic acid, and the liberation of nitrogen and electric fluid. We are certain that water and carbonic acid are liberated during muscular action, and probably azote, and light in the form of electric fluid.*

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* The inorganic compounds, which contain light, and many other principles, are most easily decomposed by the slightest increase of repulsive motion, such are the phosoxyds of ammonia.

† When any considerable change takes place in the organic matter of the body, so as to destroy the powers of life, new chemical attractions and repulsive motions take place. The different principles of which the body is composed, form new combinations. In this process, which is called putrefaction, the light of the system in land animals in combination with oxygen and nitrogen, forms nitric phosacid. In fish,

Life, then, may be considered as a perpetual series of peculiar corpuscular changes; and the living body as the being in which these changes take place. Perceptions, ideas, pleasures, and pains, are the effects of these changes. They are consequently found to be continually varying. The laws of mind then, probably, are not different from the laws of corpuscular motion. Every change in our sensations must be accompanied with some correspondent change in the organic matter of the body. These changes an extensive and philosophic chemistry may enable us to estimate.

Thus essential then is LIGHT to perceptive existence.

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during whose putrefaction no nitric phosacid is formed, it is liberated; and hence the reason for the luminous appearance of putrefying fish, an appearance, which Lavoisier supposed to be occasioned by phosphorised hydrogen. I have found by experiment, that putrefying fish are equally luminous in water boiled to expel its air and phosoxygen.

* The Torpedo, and some other animals, give out electric fluid during animal action. In man, the quantity is probably, however, too small and too slowly liberated to be ascertainable. It would be worth while to try, by a very sensible electrometer, whether an insulated muscle when stimulated into action, would not give marks of the liberation of electric fluid. To ascertain the gaseous products liberated during muscular action, would not be so difficult. An animal, or the limb of an animal, might be stimulated into muscular action for a considerable time under mercury, till its irritability was destroyed. Animals previously made to breathe phosoxygen, might be employed for this purpose, as it appears from the experiments of a celebrated philosopher, Dr. Beddoes, that they retain their irritability longer.

All organic sensitive beings with which we are acquainted, appear totally unable to exist without phosoxygen.

We may consider the sun and the fixed stars, the suns of other worlds, as immense reservoirs of light destined by the great ORGANISER to diffuse over the universe organization and animation. And thus will the laws of gravitation, as well as the chemical laws, be considered as subservient to one grand end, PERCEPTION. Reasoning thus, it will not appear impossible that one law alone may govern and act upon matter: an energy of mutation, impressed by the will of the Deity, a law which might be called the law of animation, tending to produce the greatest possible sum of perception, the greatest possible sum of happiness.*

The farther we investigate the phænomena of nature, the more we discover simplicity and unity of design.

An extensive field for sublime investigation is open to us. The laws of perceptive life as yet are but partially known. Our sensations, ideas, pleasures, and pains, depend upon causes now unknown to us.

We cannot entertain a doubt but that every change in our sensations and ideas must be accompanied with some correspondent change in the organic matter of the body. These changes experimental investigation may enable us to determine. By discovering them we should be informed of the laws of our existence, and probably enabled in a great measure to destroy our pains and to increase our pleasures.

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* The analogy between attraction and gravitation, repulsion and projection, has been mentioned before. This analogy would induce us to refer them to the same causes. It may appear absurd to suppose any analogy between these powers and the laws of life. Is not, however, perceptive action (which must uniformly be accompanied with some peculiar motion in the nervous system) analogous to repulsion and projection? Is not the association of perceptive and irritative motions a law analogous to attraction and gravitation?

Thus would chemistry, in its connection with the laws of life, become the most sublime and important of all sciences.

AN ESSAY

ON

THE GENERATION OF PHOSOXYGEN,

OR OXYGEN GAS;

AND ON

THE CAUSES OF THE COLOURS

OF

ORGANIC BEINGS.

AN ESSAY

ON THE

GENERATION OF PHOSOXYGEN,

(OXYGEN GAS)

AND ON THE CAUSES OF THE

COLOURS OF ORGANIC BEINGS

A GREAT quantity of phosoxygen is continually attracted from the atmosphere to supply the pabulum vitæ of perceptive beings. Another considerable quantity is decomposed by combustion, and absorbed in other chemical processes which take place in our globe. Since the atmospheric constitution is uniformly similar, we are led to inquire by what means a quantity of phosoxygen equal to that consumed by respiration and combustion is again supplied to the atmosphere. This inquiry is no less important than curious, as our existence itself depends on the equilibrium of gases in the atmosphere.

We have no reason for supposing that phosoxygen is generated or given out as excrementious by the locomotive organic beings which consume such immense quantities of it. During living action, water, carbonic acid, and nitrogen, are liberated from the animal, and probably electric ether and some other products.

We have no reasons for supposing that light is capable of decomposing either water or carbonic acid in their nascent state, by its attraction for oxygen. Consequently the phosoxygen of the atmosphere can in no way be supplied by the locomotive perceptive beings.

The living action of another class of beings, namely, vegetables, is the cause of the generation of the atmospheric phosoxygen.

The purification of the atmosphere by land vegetables was indeed discovered long before even its composition was known. We owe this important discovery to the immortal Priestley, who supposed that the renovation of the atmosphere by vegetables was occasioned by their power of absorbing phlogiston, an imagined product of combustion and respiration.

Dr. Ingenhouz discovered that vegetables gave out vital air when exposed to the solar light in contact with water. This philosopher attempted to prove by experiments, that the air thus generated arose from the decomposition of water. Since his experiments and those of M. Senebier have been published, we know of little that has been done in this part of chemistry; and as Lavoisier's theory of the composition of oxygen gas (phosoxygen) has been generally believed by chemical philosophers, it has been supposed that light acted no other part in the decomposition of water, than that of extricating oxygen by giving it caloric, whilst the vegetable attracted hydrogen.

In my Essay on Repulsive Motion and Light, I attempted to prove that water was decomposable by two attractions, that of a vegetable or organized hydrogen attractor for hydrogen, and that of light for oxygen. In that essay I likewise mentioned my discovery of the production of phosoxygen by the various orders of the marine cryptogamia class of plants. I shall proceed to give a detail of the experiments I have made on land and sea vegetables.

One might infer from the analysis of vegetables that they attract hydrogen and carbon, as they are their most predominant principles. It will appear from the following synthetical experiment that they attract hydrogen.

EXPERIMENT I.

A small plant of Mignonette, in a state of healthy vegetation, was inserted in a small pot under a jar of hydrogen containing twenty-eight cubic inches, and confined by mercury. The height of the mercury in the jar was accurately marked at the commencement of the experiment. It was suffered to remain in the dark for fifty hours, and then examined. The mercury had ascended a very little, and if one might judge from appearances, there was a diminution of about half a cubic inch. The jar was removed to a place exposed to the light, and suffered to remain in this situation for three days of very fine weather. It was then examined; the plant appeared uninjured, and the edges of some of its leaves were tinged yellow; there was no perceptible diminution of the mercury, from whence I concluded that phosoxygen had been generated. Solutions of sulphure of potash, and of potash, were introduced into the jar in separate vessels. A diminution took place. The remaining gas measured about twenty-five and half cubic inches, and appeared to be pure hydrogen.

Since, then, two cubic inches and a half of hydrogen disappeared in this experiment; they were most probably absorbed by the plant.

I have found by several experiments, that Mignonette always grows very well in hydrogen when supplied with water. One of these plants lived in hydrogen for a week in the dark, supplied with water by a capillary tube. At the end of this time the leaves became variegated with yellow spots, and the whole of the plant bore a sickly appearance. When these plants growing in hydrogen are deprived of water, they generally die in three or four days. In the experiment that I have just related, the earth of the pot in which the plant grew was moistened previous to its insertion, and then covered with a tin-plate top, to prevent the water from evaporating. Some plants die in hydrogen very quickly; among these are Conium maculatum, Chironea centaurium, Digitalis purpurea.

In a mixture of hydrogen and carbonic acid, I found no plant to die when exposed to light. From a number of experiments, I think I have every reason to conclude that plants directly combine with hydrogen; but as they owe their irritability, that is, their life, not to one principle alone, but to many, it is difficult to invent simple experiments to determine singly their attraction for each.

As vegetables attract hydrogen, and as it is one of their most predominant principles if it be considered as a simple substance, it must be obtained by them from the decomposition of bodies into which it enters as a constituent part.

Vegetables are totally incapable of decomposing water by their attraction for hydrogen. Some land plants give out carbonic acid, and small portions of nitrogen during the night; but there is no single instance of the production of phosoxygen from plants during the night. To determine whether the water plants which strongly attract hydrogen produce any gas in the absence of light, I made the following experiment.

Experiment II.

Into a green glass globe containing one hundred and four cubic inches, a plant of nymphæa alba in a state of healthy vegetation was inserted. The globe was filled with water, previously boiled to expel the atmospheric air, and inserted horizontally in a vessel, so as to be perfectly included from light. After remaining in the dark for four days it was examined. Two or three inconsiderable globules of gas were found in the top; which suffered no diminution when mingled with nitric phosoxyd (nitrous gas). The vegetable was pale and sickly, and water had most probably combined with it.

Water then is not decomposable by the attraction of vegetables for hydrogen, nor is it capable of decomposition by the attraction of light for oxygen.

The experiments of Priestley, Ingenhouz, and Senebier, prove that land vegetables of all kinds produce greater or less quantities of phosoxygen, when exposed to light in contact with water. I have repeated some of the experiments of Ingenhouz, and have obtained nearly the same results as that philosopher. I endeavoured to establish the fact of the decomposition of water by light and an organized hydrogen attractor by the following experiment.

Experiment III.

A glass cylinder of the capacity of ten cubic inches was filled with mercury. Two small vine leaves were introduced through the mercury, so as to detach all atmospheric air from them. The mercurial apparatus was now inserted in a vessel of cold water. Aqueous gas was passed from a vessel containing water which had been long in ebullition, through a long tube into the cylinder, where it was condensed by the cold mercury. In this manner the cylinder was filled with water which held no air in solution.

The cylinder still inverted in the mercurial trough was now exposed to light. In a very short time air globules began to form on the leaves, and in about six hours sufficient was formed to be examined. It measured two cubic inches and a half, and was nearly pure phosoxygen.*

Since in this experiment no gas of any kind was held in solution by the water, and pure phosoxygen was produced from it, it must have arisen from the decomposition of the water, by the combination of its oxygen with light, and of its hydrogen with the vegetable.

An immense quantity of water then must be constantly decomposed by the attractions of land vegetables and of light; and a considerable quantity of phosoxygen must be continually supplied to the atmosphere from this source.

Carbonic acid, as well as water, is formed in large quantities by combustion, fermentation, &c., and is continually liberated during the living action of perceptive beings. Now as this gas is considerably heavier than atmospheric air, if it was not perpetually decomposed by some means, the lower strata of the atmosphere would soon become composed of it, the supply of phosoxygen would be cut off from locomotive organic beings, and perception, thought, and action, would cease to exist. As carbon forms one of the most predominant principles of land vegetables, we might conclude almost without experiment that the carbonic acid of the atmosphere is somehow decomposed by them. To determine whether land vegetables were capable of decomposing carbonic acid by their attraction for carbon, unassisted by the attraction of light for oxygen, I made the following experiment.

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* [The author, in his Lectures on Agricultural Chemistry, (the 5th lecture,) when treating of the functions of the leaves of plants, referring to this experiment, makes the following remark:—"I obtained a considerable quantity of oxygen in an experiment made fifteen years ago, in which vine leaves were exposed to pure water; but on repeating the trial often since, the quantities have been very much smaller. I am ignorant whether this difference is owing to the peculiar state of the leaves, or to some confervæ which might have adhered to the vessel, or other sources of fallacy."]

Experiment IV.

A small plant of chironea centaurium, growing in a pot of very dry earth, was inserted under mercury, in a jar filled with very pure carbonic acid. It remained in a dark closet for four days, and was then examined. The mercury in the jar had ascended a very little, and the plant had a pale and sickly appearance. After the carbonic acid was taken up by potash, there remained in the jar a very small portion of an incombustible gas.

From this experiment it is evident that the attraction of plants for carbon is too weak to enable them to decompose carbonic acid; but that they combine with small portions of it, and thus supersaturated with oxygen become white and sickly.

Light alone effects no decomposition of carbonic acid, not even in its concentrated state in the electric spark.

To determine whether plants were capable of decomposing carbonic acid, assisted by the attraction of light for oxygen, I made the following experiment.

Experiment V.

I planted in each of two pots filled with moist earth, a small arenaria tenuifolia. The two plants were of equal weights, and nearly similar. They were inserted into two jars, containing each fourteen cubic inches, one of which was filled with nitrogen, and the other with carbonic acid. The jars were inverted in mercury, and exposed to the solar light for four successive days of fine weather in the month of July. The plant in the carbonic acid now looked well and healthy, that in the nitrogen dark and faded. The mercury in the jar filled with carbonic acid, had ascended considerably. The gases were now examined. In the jar with the carbonic acid there was a deficiency of 2·3 cubic inches. After the carbonic acid was taken up by potash, the remaining gas measured two cubic inches, and proved to be phosoxygen. In the jar containing nitrogen, the gas was not diminished more than three-tenths of a cubic inch. On the introduction of sulphure of potash a small diminution took place, amounting to six-tenths of a cubic inch. This diminution was, I suppose, owing to the absorption of phosoxygen formed from the decomposition of the water of the plant.

From this experiment, which I have repeated two or three times on different plants with similar results, I conclude that carbonic acid is decomposable by the force of two attractions; that of light for oxygen, and that of certain organised carbon attractors for carbon.

Thus then we find in the vegetable world a source for the decomposition of the carbonic acid and water formed in respiration and combustion. It is chiefly by the means of vegetables that the equilibrium of the atmosphere is preserved, and on their chemical influence, and that of light, do we depend for our existence.

Animals may be considered as absorbing in their respiration phosoxygen, and as taking in in their nutriment, hydrogen, carbon, nitrogen, and oxygen, and giving out perpetually these principles in new combinations; water, carbonic acid, and probably ammonia and electric fluid. On this perpetual series of changes their life appears to depend. Vegetables, on the other hand, are continually absorbing water, carbonic acid, and probably ammonia and nitrogen, and assisted by light in the exercise of their organic functions giving out phosoxygen.

Without vegetables animals would cease to exist, and were locomotive perceptive beings removed from the earth, vegetable life would soon be at an end.

The vegetation of land plants then may be considered as the great source of the renovation of the atmosphere of land animals.

We shall proceed to investigate the manner in which the inhabitants of the ocean are supplied with phosoxygen. For as the experiments in my last essay prove, they continually require it as well as land animals.

I have found by experiments, that water equally dissolves phosoxygen and nitrogen, and that nitrogen is not expelled from water by phosoxygen. The myriads of inhabitants that people the immensity of the ocean are continually absorbing phosoxygen, and giving out carbonic acid, &c.

The sea water may be considered as continually dissolving atmospheric air. Now if there were no source for the absorption of the nitrogen and carbonic acid held in solution by water, and for the production of a quantity of phosoxygen equal to that absorbed by fish, the waters of the ocean would soon become saturated with nitrogen and carbonic acid, and the perceptive inhabitants of it would cease to exist.

As land vegetables are the renovators of the atmosphere of land animals, analogy led me to suppose that sea vegetables must be the preservers of the equilibrium of the atmosphere of the ocean.

I first attempted to determine whether like land vegetables, they produced phosoxygen during the presence of light; for this purpose I made the following experiment.

EXPERIMENT VI.

Into a green glass globe containing a hundred and eighty four cubic inches of sea water, I inserted a large sprig of fucus natans, another of conferva fœniculacea, and three or four pieces of an ulva, with the name of which I am unacquainted. The globe was exposed to the solar light. It had not been exposed many minutes, when I beheld with great pleasure, globules of gas forming on the vegetables, which in a short time were raised by them to the top of the globe. In about a quarter of an hour, a large globule was formed, and in about two hours, sufficient to measure. It was one cubic inch and half, and by trial with nitric phosoxyd, proved to be $\frac{59}{100}$ parts phosoxygen, and $\frac{41}{100}$ azote.* During this experiment, the thermometer stood at 47°, and the barometer at 29·9.

Having ascertained that a compound gas was produced from water by the marine cryptogamiæ, with a larger proportion of phosoxygen than atmospheric air, I made the following experiment to ascertain whether all the marine cryptogamia produced this gas, and whether it was purer when the dissolved air was expelled from the water by boiling.

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* A gas undiminishable by nitric phosoxyd.

Experiment VII.

Into a green glass globe containing a hundred and four cubic inches, filled with sea water previously well boiled to expel the atmospheric air, I inserted two cubic inches of fucus fibrosus. The globe was inserted in a vessel of boiled water, and exposed to a bright sunshine. Soon after its exposure the fucus became covered with a vast number of globules of air, which raised it to the top of the globe, and then detached themselves to form larger globules. In about four hours sufficient gas was formed to ascertain the quantity and quality of it. It measured two cubic inches and a quarter,—the mercury in the barometer standing at 30 inches, and the thermometer at 54°. By trial with nitric phosoxyd it proved to be $\frac{71}{100}$ phosoxygen, and $\frac{29}{100}$ azote.

The globe being exposed the next day for six hours in a very bright sunshine, three cubic inches were formed, about $\frac{76}{100}$ phosoxygen, and $\frac{24}{100}$ azote.

The day after, the globe was exposed for nine hours and half of moderate weather; three cubic inches and half were formed, of nearly the same quality as the last.

On the fourth day of this experiment the sun shone very bright for five hours; two cubic inches were formed, $\frac{18}{100}$ azote, and $\frac{82}{100}$ phosoxygen.

All the gas in this experiment which was not diminished by azotic phosoxyd, was put into a vessel, and when examined, proved to be two-thirds nitrogen, and one-third carbonic acid.

From this experiment it appears that the fuci produce phosoxygen during the presence of the solar light. The nitrogen produced in this experiment most probably arose from a small portion of atmospheric air, which water still holds in solution though boiled.

EXPERIMENT VIII.

Two cubic inches of ulva dichotoma were inserted into the globe containing a hundred and four cubic inches, filled with water previously boiled. It was inserted in a jar containing water of a similar kind. This globe was exposed for four days successively to the solar light. On the first day, in eight hours of sunshine, three cubic inches and half of gas were formed, $\frac{70}{100}$ phosoxygen, and $\frac{30}{100}$ azote.

On the second day, when the sunshine was uncommonly bright, in six hours two cubic inches and half were formed, of $\frac{77}{100}$ phosoxygen, and $\frac{23}{100}$ azote.

The third day was showery, and the sun often obscured; in nine hours but two cubic inches and quarter were formed, containing $\frac{76}{100}$ phosoxygen.

The sun was out and very bright continually for seven hours on the fourth day; two cubic inches and half were formed, $\frac{83}{100}$ phosoxygen, and $\frac{17}{100}$ azote.

EXPERIMENT IX.

Into the green glass globe of a hundred and four cubic inches, filled with boiled sea water, two cubic inches of conferva littoralis were inserted, and the same precautions being taken as in the last experiment, the globe was exposed to the solar light for four hours; in this time five cubic inches of gas were formed, of the quality of 76.*

The next day the globe was exposed for seven hours of sunshine, and six cubic inches were formed, of the quality of 78.

The day after, the globe was again exposed for eight hours; five cubic inches were formed, of the quality of 81.

On the fourth day, the weather in the morning was cloudy; but in the afternoon the sky brightening, it was exposed for three hours and half, and in this time two cubic inches were formed, about 86.

The gas produced in this experiment, unalterable by nitric phosoxyd, was chiefly nitrogen.

During the whole course of these experiments, I perceived no sensible difference in the production of gas corresponding to difference of temperature.

From these experiments it is evident that the different orders of the marine cryptogamia are capable of decomposing water, assisted by the attraction of light for oxygen.

I discovered by analysing the sea-weeds, that they were composed chiefly of hydrogen, carbon, and nitrogen.

As carbon is incapable of solution in water, it is evident that the sea-weeds must obtain it from the decomposition of some of its combinations. I found that sea-weeds placed in water saturated with carbonic acid, produced no alteration in it in the dark for some days, except that of disengaging portions of the dissolved carbonic acid.

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* To prevent unnecessary repetitions, I shall for the future express the quality of gases by giving the quantity of phosoxygen in 100 parts, from whence the quantity of azote will be known.

To determine their capability of decomposing it, assisted by the attraction of light for oxygen, I made the following experiment.

Experiment X.

Into a vessel containing sixteen cubic inches of carbonic acid, two cubic inches of conferva scopularis were inserted. The vessel was inverted in mercury, and exposed to the solar light. It remained in a bright sunshine for eight hours, and at the end of that time was examined. The gas was diminished to eleven and half cubic inches, so that there was a deficiency of five cubic inches and half. Of the eleven and half cubic inches remaining, two were phosoxygen, the remainder pure carbonic acid.

To determine that the whole of the phosoxygen produced in this experiment did not arise from the decomposition of the water in the vessels of the plant, I made the following comparative experiment.

Experiment XI.

Two vessels, containing each ten cubic inches, were filled, one with carbonic acid, the other with nitrogen, under mercury. Into each of these, sixty grains of conferva littoralis, previously wiped dry, were inserted. The vessels were exposed to the solar light for six hours, and then examined. The carbonic acid was diminished two cubic inches, the nitrogen not more than one-fourth of an inch. One cubic inch and seven-tenths of phosoxygen was found mingled with the carbonic acid, with the nitrogen only six-tenths of phosoxygen.

EXPERIMENT XII.

Two glass globes, containing a hundred and four cubic inches each, were filled, one with boiled sea water, and the other with sea water holding in solution carbonic acid. Into each of them was inserted a hundred grains of fucus natans. They were then exposed to the solar light for four hours, and at the end of that time examined. In the vessel containing carbonic acid and water, three cubic inches of gas were formed, sixty-four parts phosoxygen, sixteen carbonic acid, and twenty nitrogen. In the vessel with water, one cubic inch and six-tenths, of the quality of 75.

From these experiments it is evident that carbonic acid is decomposable by the attraction of the marine cryptogamia for carbon, and that of light for oxygen.

Since nitrogen is one of the principles of the marine cryptogamia, and since it is held in solution by water in a very large proportion in atmospheric air, it occurred to me that the marine cryptogamia attract it from the atmospheric air dissolved in the sea, and combine with it. To ascertain this I made the following experiment.

EXPERIMENT XIII.

A glass jar containing thirteen cubic inches, was filled with nitrogen under mercury. Into this, two cubic inches of conferva purpurascens were inserted, and the quantity of gas in the jar accurately determined. Thus disposed, the whole apparatus was suffered to remain in the dark; the mercury in the thermometer standing at 61°. After four days the apparatus was examined; the mercury had ascended considerably, and the gas was measured. There was a deficiency of a cubic inch and half. I could not discover that any gas had been given out by the plant.

Experiment XIV.

A small glass vessel containing eight cubic inches, was filled with nitrogen under mercury. Into this two cubic inches of fucus vesiculsous were inserted. The apparatus was exposed to the solar light. After remaining for two days of fine weather, the gas was examined; there was a deficiency of a cubic inch and quarter, and half an inch of the gas remaining was phosoxygen. A cubic inch and three quarters of nitrogen were consequently absorbed by the plant.

The similarity of the constitution of the atmosphere depends on the equilibrium between the gases absorbed, and those generated.

Locomotive perceptive beings are continually absorbing phosoxygen in their respiration, and giving out carbonic acid, water, &c. Vegetables, assisted by the attraction of light for oxygen, are continually decomposing water and carbonic acid, of which the oxygen is liberated in combination with light, and the hydrogen and carbon combine with them.

Nitrogen is probably liberated during animal action; and this principle is likewise absorbed by some of the vegetables.

The equilibrium of the gases held in solution by the waters of the ocean is preserved by the marine cryptogamia class of vegetables.

The marine animals are continually absorbing the phosoxygen of the atmospheric air held in solution by water, and giving out carbonic acid, and probably other principles.

The marine vegetables are continually absorbing the nitrogen of the atmospheric air held in solution by water; and assisted by the attraction of light for oxygen, decomposing water and carbonic acid, combining with the hydrogen and carbon, and liberating the oxygen in combination with its attractor light.

Thus the sea-weeds that every where cover the rocks at the bottom of the ocean, are continually giving out phosoxygen during the presence of light. In the deeper parts of the ocean the phosoxygen, continually formed in small globules, is probably almost wholly dissolved by the sea-water before it can reach the atmosphere above; but near the sea-coasts where the marine confervæ are found in immense quantities, the greater portion of the phosoxygen formed on their leaves is liberated into the atmosphere.*

From this discovery we are enabled to account for a number of phænomena before inexplicable.

1. In what manner the equilibrium of gases dissolved in the ocean is maintained.
2. Why the sea air is purer than that of the land.
3. Why the air near the sea coasts is even purer than that on the ocean.†

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* The following is an account of the composition of the atmosphere in different parts of Mounts Bay in Cornwall, where the experiments on the marine cryptogamia were made. On a calm morning in May 1798, the mercury in the barometer standing at 29·3, and that in the thermometer at 55, the air in the middle of Penzance contained 28·5 per cent. phosoxygen. The air on the rocks of the sea-shore 30. The air on the sea about a furlong from the shore, nearly the same proportion; at a quarter of a mile from the shore, the proportion was 30·12. About a mile, 30·1. At two miles 29·12, and at four miles 29. On a calm morning the air at the land's end was 29·13.

† [These were inferences from erroneous experiments. Vide his "account of a new eudiometer" in this volume, in which they are corrected.]

Nature then has catenated together organic beings, and made them mutually dependent on each other for their existence, and all dependent on light.

A privation of light would be immediately destructive to organic existence; vegetation would cease; the supply of phosoxygen would be quickly cut off from animals; the lower strata of the atmosphere would become composed of carbonic acid, and perception and volition would exist no longer.

The irritability of the living fibre of plants appears to depend on the equilibrium between its principles. This equilibrium is preserved by light. The principles of the fibre are chiefly carbon, hydrogen, oxygen, and light. Some of them contain portions of nitrogen. The irritable vegetable fibre appears to be a phosoxyd similar in some respects to the animal fibre, but containing smaller proportions of nitrogen and light. Different vegetables possess different degrees of irritability. The mimosa sensitiva, the dionea muscipula, and some other plants, possess an irritability so exquisite as to border on the sensibility* of animals. The irritability of the sea-weed is so indistinct as to be scarcely perceptible. The more perfect land vegetables, possessed of a vascular system, require a supply of food slowly and regularly. They possess a power of giving out as excrementious, the principles which are noxious to their existence, and by a beautiful economy of nature are capable of reproducing their species.

The marine cryptogamia, in their organization and functions, are very much inferior. Attached to the rocks on the bottom of the ocean, they assimilate to them nitrogen and water, and assisted by the attraction of light for oxygen, combine with hydrogen and carbon; they appear to possess no regular vascular system for the circulation of fluids, and absolutely in their generation and growth appear to follow the law of assimilation of particles, similar to that by which minerals are crystallised.

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* The observations of a most ingenious philosopher, Dr. Darwin, render it probable that some of the more perfect vegetables possess sensibility. See Darwin's Zoonomia, vol. i. p. 101 and 102.

The light entering into the composition of vegetables appears not only to be the principle on which their irritability more peculiarly depends, but likewise to be the principle to which they as well as all substances chiefly owe the differences of their colours. We do not assert that light is the general colouring principle; this would be absurd in the present state of our knowledge. We shall attempt to demonstrate that many vivid colours depend on combined light.

Almost all the simple substances and the combinations of the simple substances that contain no light, are either pellucid, white, or black. Among these are the gases, water, alcohol, the acids, the alkalies, the pure earths, phosphorus, sulphur, when in its pure state and uncombined with light,* carbon, and the different metallic substances which in general are either white, or black and white, that is, grey. Copper, which is yellow, appears to contain light, and probably some other metals.

The compounds into which oxygen enters, and which contain no light, as oxyds, acids, &c. are likewise generally either transparent, white, or black; transparent, as the simple acids and some of the oxyds; white, as the oxyds of lead, zinc, and antimony; black, as the oxyd of iron.

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* Sulphur, in its common state, evidently contains a portion of light, as is evident from the experiment mentioned in that part of the last essay which relates to phosphorescent bodies.

The inorganic compounds containing phosoxygen, are almost all of vivid colours; and these colours appear to be in some measure correspondent to the quantities of light entering into their composition. A small quantity of light combined with oxygen and metallic bodies, renders them either brown, as the argentic and ferric phosoxyds,* or purple, as the auric phosoxyd. Bodies containing a larger proportion are either green, as the cupric phosoxyd, or yellow, as the tungstic phosoxyd. The phosoxyds containing a still larger portion of light, are bright red, as the plumbic and mercuric phosoxyds. The chromic phosacid, as was observed in the last essay, likewise owes its colour to combined light.

The phosoxyds lose their colours when light is subtracted from them in combination with oxygen.

When the tungstic phosoxyd is exposed to light, it gives out phosoxygen, and turns from yellow to blue.

The mercuric phosoxyd, on the subtraction of a portion of its light in combination with oxygen, becomes brown.

The plumbic phosoxyd likewise becomes brown on a subtraction of a portion of its light and oxygen; when the whole of its light is subtracted, it becomes white.

The sulphuric acid combines with the plumbic oxyd, but not with the plumbic phosoxyd. When it is poured on the last, phosoxygen is given out, the phosoxyd gradually loses its colour with its light and oxygen, becomes white, is converted into an oxyd, and combines with the acid.

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* In my last essay, treating of the phosoxyds, I have neither mentioned the ferric, cupric, or blue cobaltic phosoxyds, because I am possessed of no facts which absolutely prove the presence of light in these bodies. This, however, is extremely probable, not only from analogy, but from the phænomena observed in their oxydation. The variety of colours of the oxyds of iron combined with earths, &c. depend most probably on the different quantities of light entering into their composition.

The green prussiate of iron, on a subtraction of oxygen and light from it, becomes blue.

The whiteness of etiolated vegetables is occasioned by the deficiency of light; the different shades of green in the leaves of vegetables depend on the light entering into their composition; and the fine colours of the different flowers appear to be produced by combined light, as will appear from the following experiments and observations.

EXPERIMENT XV.

Two lettuces of equal size, both fine, healthy, green plants, were planted in two pots filled with moist earth; one of these plants was inserted in a jar filled with carbonic acid, and deprived of light. The other was exposed to light and atmospheric air. In about twelve hours the inferior leaves of the plant in the dark began to fade, which obliged me to remove it out of the jar filled with carbonic acid, and expose it to atmospheric air. It remained deprived of light for six days, during which time it was plentifully supplied with water. At the end of this time the leaves were very pale, the lower ones perfectly white; on the upper ones a few spots of green remained. It was again deprived of light, and daily supplied with water. After remaining for a week it was again examined: the leaves were now quite white.

The plant which had been exposed to light and air was now examined. It was of a fine lively green, and much larger than the etiolated plant. Equal weights of the leaves were analysed by destructive distillation. The only perceptible difference in the products was a larger proportion of carbonic acid and water in the white, and in the green more hydrogen and residual carbon. I obtained from some of the remaining green leaves, by a low heat, a small quantity of phosoxygen mingled with carbonic acid; from the white, carbonic acid alone.

I have often obtained from the green leaves of vegetables, by applying a low heat very gradually, small portions of phosoxygen; from which it appears that the green colours of vegetables depend on the light, or the phosoxygen entering into their composition, and the whiteness of etiolated plants, to the deficiency of light in their composition.

Plants, in the process of etiolation, lose the light combined with their leaves, and become white. They are as well capable of combining with a larger proportion of light, and thus supersaturated with light, become bright coloured red or orange, as will appear from the following experiment.

Experiment XVI.

I procured two lettuces and two plants of sorrel (rumex acetosa) of nearly the same size. One of each kind was planted in moist clay, which had been before proved to be fit for vegetation, the other in silicious sand mingled with a little clay. The plants in the clay were placed under a shady wall and daily watered; those in the sand were placed in a situation constantly exposed to the sun, and were supplied with very small quantities of water. In about six days the plants exposed to light became spotted with red and orange in many parts of their leaves. These spots continued to increase in number and size, and in about a fortnight the colour of the upper parts of the leaves of the lettuce were changed to a dark red. The upper parts of the leaves of the rumex acetosa were red, and the lower of a dusky green. The plants in the shade were of a fine green. Comparative analyses of equal parts of the green and the red leaves were made. The results of three experiments were, that the red leaves contained more phosoxygen, hydrogen, and residual carbon, and the green more carbonic acid and water.

From this experiment it is evident that the red or brown colours of leaves too much exposed to light, is owing to their containing a superabundance of light, which, in the analysis, combined with oxygen.

The different colours of the leaves of different plants then, most probably depend on the different quantities of light, oxygen, and carbon, entering into their composition.

Flowers, like leaves, depend for their vivid colours on the light entering into their composition. The red flowers, as the rose, anemone, &c. appear to contain the greatest quantities of light. I have found by experiment that red rose trees, when carefully included from light before their flowers begin to appear, and supplied plentifully with water and carbonic acid, produce flowers almost white.

By making comparative analysis of the white and red roses, from several experiments, I think I have every reason to conclude that the red roses owe their colours to combined light.

By distilling muriatic acid from red rose leaves, I discovered that a small portion of the acid was converted into muriatic phosacid, which proves that the red rose leaves contain light and oxygen.

The pink, orange coloured, and yellow flowers appear to contain smaller proportions of light; the dark purple and blue still less. In the white flowers I have never been able to detect the presence of light. The fine colours of fruits, which depend entirely on their exposure to light, most probably depend, like those of flowers, on the light entering into their composition.

I have made some experiments on the marine cryptogamia, which seem to prove that they are governed by the same laws of colour as land vegetables. I have succeeded in blanching the dark coloured confervæ by secluding them from light, and their different colours appear to depend on the different quantities of light, oxygen, and carbon, entering into their composition. Zoophyta and fish, the perceptive inhabitants of the ocean, appear to depend on similar causes for their colours. I have observed that the zoophyta exposed to light are uniformly brighter coloured than those which have been by any means secluded from it, and I succeeded in altering the colours of two sea anemones from a dark red to a pale pink, by secluding them from light.

The parts of fish which are exposed to light, as the back fins, &c. are uniformly coloured red, brown, green, yellow, blue, &c. in different fishes; but the belly, which is deprived of light, is uniformly found white in all of them.

Rational analogy alone would induce us to suppose that the colours of land animals depend upon the same causes. Independent of this, we have facts and experiments sufficient to establish this truth.

The birds that inhabit the tropical countries are much brighter coloured than those of the north. Those parts of birds which are not exposed to light are uniformly pale. The feathers on the bellies of birds are generally pale or white: the back, which is exposed to light, is almost always coloured: the breast, which is partially exposed in most birds, is brighter than the belly, and paler than the back. Those parts of the same feather which are exposed to light, are uniformly bright coloured, when compared with those parts that are deprived of its influence.

The colours of quadrupeds depend on similar circumstances. The beasts of the equatorial countries are uniformly brighter coloured than those of the polar countries. The hair on the parts of beasts not exposed to light is uniformly paler than that covering the parts exposed to its influence; and it affords a striking proof of the truth of this theory, that some of the northern animals are dark coloured in summer, and white or pale in winter.

The human being is equally dependent for its colour on the influence of light.

The colour of the skin depends on the colour of the rete mucosum. This is white in the people that inhabit the north of Europe, copper coloured in the American, and black in the Negro. The cuticle, which is of the same colour, and equally pellucid in the different species of mankind, appears to contain no oxygen or light, and is most probably composed of carbon, hydrogen, and nitrogen. The rete mucosum is probably composed of carbon, oxygen, hydrogen, and nitrogen. The comparative quantities of carbon and oxygen in it appear to occasion the differences of its colours. These quantities depend on the quantity of oxygen attracted from it by light.

Light acting on the rete mucosum of the African, is continually subtracting oxygen, the principle to which its whiteness is owing. When the oxygen is subtracted, the carbon becomes the predominant principle, and hence that blackness peculiar to the negroes and the inhabitants of the torrid zone.* In the Americans, the inhabitants of Asia, and the southern Europeans, the colour varies from dark copper coloured to pale tawny. These people are less exposed to light than the Negroes, consequently their skin contains a larger proportion of oxygen. The inhabitants of the northern countries, who are still less exposed to light, are white: their rete mucosum contains its full proportion of oxygen.

In Europeans we find the parts of the body exposed to light, darker coloured than those that are covered.

Women, who are less exposed to light, are fairer than men.

A subtraction of oxygen from the rete mucosum by any means, uniformly blackens it. The application of sulphure of potash blackens the skin almost instantly, as I have found by experiment. By combining with oxygen the rete mucosum is uniformly whitened. Dr. Beddoes whitened the fingers of a Negro by muriatic phosacid, which appears capable of giving out a small portion of oxygen and of still retaining all the light entering into its composition.

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* [The cause of the darkening effect of the sun's rays on the rete mucosum or surface of the *cutis vera*, remains to be ascertained; it is opposite to their effect on the hair, which is bleached by exposure to light: when most strongly marked, as in the "sun-burnt," it is connected with inflammatory action.]

The different colours of different parts of the organic matter of the body depend chiefly on the light and oxygen entering into their composition.

The red muscles, as we attempted to prove in the last essay, are phosoxydated compounds, and probably owe their colour to the light entering into their composition. From the white colour of the nerves, and their office of conducting, and being excited into sensible action by condensed light, we may conclude that they contain no light in their composition. The arterial blood owes its fine colour to the light and oxygen entering into its composition; the venous blood is black from a deficiency of light and oxygen.

The colours of the cheeks depend on the number of blood vessels in the cutis, the quantity of blood circulating through them, the colour and thickness of the rete mucosum and the thickness of the epidermis. Hence those people who have a thin epidermis, a white rete mucosum, and a number of blood vessels in the cutis, have very rosy cheeks. When the veins on the surface of the cutis are more numerous than the arteries, the colour of the cheeks will approach more to dark red or purple; when, on the contrary, the arteries are more in number than the veins, the colour will approach nearer to fine vermilion, which is the hue of health.

Whatever increases the general action of the arterial system, reddens the colour of the cheeks: general stimuli produce this effect. Certain passions of the mind more peculiarly occasion an increased action of the vessels of the skin of the cheeks.

Though the differences of the colour of the skin in different nations must have originally depended entirely on the chemical influence of light; yet when these colours are once produced, their changes are in some measure dependent on the mind. When certain colours are considered as beautiful, the generating imagination makes them hereditary, and the chemical changes from the influence of light are more slowly produced. Thus Europeans, though exposed to light in the African countries, do not become black, but in a great length of time; and Negroes, though deprived of light, their accustomed oxygen attractor, are not blanched for many generations.

ADDENDA.

THE experiments on the generation of heat were made long before the publication of Count Rumford's ingenious paper on the heat produced by friction. His experiments alone go far to prove the non-existence of caloric, and when compared with the second and third experiments in my essay, will, I should conceive, leave no doubts on the mind of the impartial and philosophic reasoner.

As vegetables depend for their life on a certain equilibrium between their principles, they must be continually supplied with the different substances by which this equilibrium is maintained.

A supply of water, carbonic acid, light, &c. is essential to the true vegetative process. The greater number of vegetables die in a short time, when deprived either of water or carbonic acid.

I should suppose, that if it were possible to deprive carbonic acid, hydrogen, and nitrogen, of the water they generally hold in solution, they would be soon destructive to all vegetables. The gases that I made use of in my experiments probably contained much water, as I always filled my vessels under water, and then transferred them to a mercurial trough, the surface of which was covered with water saturated with the gas with which the experiment was to be made. After the insertion of the plant, the height of the mercury was marked; from whence the absorption of gas could easily be known.

In carbonic acid confined in this manner under mercury, many vegetables live for a considerable time. Among these vegetables are the different species of arenaria, the chironea centaurium, and the sedum anglicum.

As I was obliged to be methodical in my last essay, I have only mentioned one experiment to prove the decomposition of carbonic acid by plants, that on the arenaria tenuifolia, because it was the most conclusive. I do not, however, suppose that the whole of the phosoxygen produced in that experiment arose from the decomposition of carbonic acid; some of it probably arose from the decomposition of the water dissolved by it.

Some plants die in carbonic acid in ten or twelve hours; among these are water plants in general, and the different species of rumex.

The generation and growth of vegetables, though apparently very complex processes, depend on the simple laws of attraction and repulsion. The apparent regular expansion of a vegetable germ is produced by its power of attracting and assimilating to itself a number of principles. Vegetation only differs from crystalization, as being a more complex process. In crystalization certain particles, homogeneal in relation to each other, combine together according to the laws of their reciprocal attractions and repulsive motions, to form regular figures. In vegetation, a compound substance (that is, a germ) is capable of attracting different principles. When these principles are assimilated to it, it possesses the power of attracting new ones, and thus shoots out into leaves of different forms, and continually gaining new attractive powers, at length produces flowers and fruits.

To illustrate this, we will suppose a germ of a certain figure, composed of carbon, hydrogen, and oxygen, in certain proportions. The combined attraction of hydrogen and carbon for oxygen, and that of oxygen for hydrogen and carbon, enables the germ to combine with water and carbonic acid. These principles become assimilated with it, it consequently increases in bulk, and rises above the soil which gave it birth. When acted on by light, a new chemical process takes place; the superabundant water and carbonic acid, the oxygen of which rendered it white, are decomposed by the attraction of light for oxygen, and probably by the mutual attractions of hydrogen and carbon for each other. A new equilibrium of principles now takes place; the plant becomes capable of combining with portions of phosoxygen, and its colour gradually changes from white to green. In this manner the vegetative process proceeds; from the assimilation of new principles new attractive powers are continually gained, and different parts of the plant become of different forms and colours.

It is probable that the process of animalization is similar to that of vegetation, and different only as being more complex. Indeed, as the principles of living beings become more numerous, the delicacy of organization increases.

The combination of particles, homogeneal in relation to each other, produces regularity of form. The combination of different principles, according to certain laws of attraction, produces irritability. Sensibility may be the result of an infinitely more complex organization.

Almost all the vivid colours with which we are acquainted, belong to the substances which contain light. We do not, however, mean to assert that colour is a necessary effect of combined light; on the contrary, many bodies that contain a considerable quantity of light in their composition, are white, black, or pellucid; white, as the phosnitrates, black, as the phosoxyd of manganese, and pellucid, as the phosacids.

To call any principle the colouring principle, is absurd. The colours of bodies, as we attempted to prove in the doctrine of light, depend on their capacities for subtracting the repulsive motion of light. The colours of compound substances are found in general to be totally different from, and to bear no relation to, the colours of their constituents. Two transparent substances combining, often produce an opaque body; and two white constituents, a vivid coloured compound.

EARLY MISCELLANEOUS PAPERS

FROM

NICHOLSON'S JOURNAL,

JOURNALS OF THE ROYAL INSTITUTION,

AND

PHILOSOPHICAL TRANSACTIONS.

EXTRACT FROM

A LETTER TO MR. NICHOLSON,

ON CERTAIN FACTS RELATING TO HEAT AND LIGHT, AND ON THE DISCOVERY OF THE DECOMPOSITION OF THE CARBONATE AND SULPHATE OF AMMONIAC.*

An experiment on the collision of flint and steel in vacuo, and in carbonic acid, published in my Essay on Heat and Light, differs considerably in its results from a similar one made long ago by the ingenious Mr. Hawksbee.† In repeating my experiments a number of times under new circumstances, I have discovered the cause of this difference. When the gun-lock is snapped in carbonic acid, or in water, if a sharp and thin flint be made use of, and the springs be strong, a faint red light is generally perceptible: but if the flint be thick, and sufficiently sharp only to strike off particles from the steel without suffering considerable abrasion of its own parts,—though vivid sparks are produced in the atmosphere, not the slightest luminous appearance is perceptible in carbonic acid. If, instead of flint, fluor-spar, phosphate of lime, or sugar, be rubbed pretty briskly against steel in carbonic acid, as much light is

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[* In less than twelve months from the time of publication of the preceding Essays, the Author's confidence in the theory which he had advanced in them respecting light and its combinations was shaken. His scepticism on the subject, arising out of a more extensive experience, and a knowledge of new facts, he expressed in a letter to Mr. Nicholson, inserted in his Journal,—the Number for February, 1800, of which the above is an extract. It offers a striking example, how little he was under the bondage of that "consistency in regard to opinions" which he considered as "the slow poison of intellectual life."]

† Phil. Trans. Vol. xxiv. p. 2165.

produced as when they are rubbed against it in common air. These facts induce me to believe that whenever light is produced by the collision of flint and steel in carbonic acid, it arises from the collision of small particles of flint against each other, and never from the ignition of steel. I have often examined in a microscope the small particles of steel struck off by flint in carbonic acid; the edges are generally deprived of metallic lustre, and exhibit an appearance of fusion. It is probable, however, that this appearance is owing to a partial oxydation of the particle, from the decomposition of the water held in solution by carbonic acid. In Mr. Hawksbee's experiments, the apparatus was contrived in such a way as to produce perpetual abrasion of particles of flint. In my experiments, the flint was not sufficiently thin to produce light in carbonic acid, consequently it ought to have produced none in vacuo: but if (as the facts I am about to detail render probable) the light produced by flint, fluor-spar, phosphate of lime, &c. on collision, be electrical, there are strong reasons for believing that in a Torricellian vacuum, or in a vacuum formed by the absorption of carbonic acid, by a solution of potash sufficiently concentrated to form a solid compound with it, no light would be visible.

Mr. T. Wedgwood found that fluor-spar, phosphate of lime, flint, &c. were luminous, not only when heated, but when struck together, and that under water, or in any kind of air. Scheele discovered that fluor-spar, after calcination, lost its phosphorescence. I exposed to a long-continued red heat fluor-spar, phosphate of lime, sulphate of strontian, sulphate of barytes, glass, sulphate of lime, and carbonate of lime, all of which were before phosphorescent, and produced light by collision under water.

After being suffered to cool in the light, they were placed on a heated iron successively. The fluor-spar, the phosphate of lime, and the sulphate of strontian and barytes were not phosphoric at any temperature. The calcareous spar, which had lost a portion of its carbonic acid, and the gypsum, were nearly as luminous as before; the phosphorescence of the glass and flint was barely perceptible.

Two pieces of calcined fluor were now rubbed together; they produced as much light as before. The phosphate of lime, the calcareous spar, and the gypsum had lost their coherence, so that the pieces could not be rubbed against each other with sufficient force. The sulphate of strontian and barytes, the glass and the silex produced as much light as before on collision.

I found that all these bodies were non-conductors of the electric fluid. On rubbing a large crystal of quartz with flannel, it became highly electric. Fluor-spar was likewise made electric when heated and strongly rubbed. To prove, however, more satisfactorily whether the light produced by the collision of two non-conductors was electric, two cylinders of glass were struck against each other, so as to produce light, and one of them was placed in contact with a Leyden phial. After a number of collisions, on applying a conductor to the phial, I procured a small spark.

Two pieces of pyrites, sufficiently hard to cut glass, and extremely brittle, produced an immense quantity of light when struck together in the atmosphere; but not the slightest luminous appearance under water. This body is a good conductor of the electric fluid. Do not these facts go far to prove that light, when produced by the collision of bodies in water, or non-respirable air, is electric, and generated by the rapid transmission of electrical fluid, excited by collision between two non-conducting surfaces, to a conducting body? And, as iron can be heated to a degree at which it is capable of decomposing oxygen gas, in a non-respirable air without being luminous; and as pyrites is not luminous under water, is it not probable that light is accidental to, and not necessarily produced by, high temperature?

The admission of such inferences would be favourable to my theory of the combinations of light; but facts have occurred to me with regard to the decomposition of bodies which I have supposed to contain light, without any luminous appearance. Till I have satisfactorily explained these facts by new experiments, I beg to be considered as a sceptic with regard to my own particular theory of the combinations of light, and theories of light in general. On account of this scepticism, and for other reasons, I shall in future use the common nomenclature; excepting that as my discoveries concerning the gaseous oxyde would render it highly improper to call a principle, which in one of its combinations is capable of being absorbed by the venous blood, and of increasing the powers of life, azote, I shall name it, with Dr. Pearson, Mr. Chaptal, and others, nitrogen,—and the gaseous oxyde of azote, the properties and composition of which have been misunderstood by the chemists, who gave it that name, nitrous oxyde.

Many months ago, I made a number of experiments on the composition, analysis, and decomposition of the ammoniacal salts. These experiments have afforded me curious and interesting results; but a wish to complete the investigation relating to the nitrous oxyde has prevented me from pursuing them to their full extent.

Among these results, as affording useful practical applications, I shall mention the decomposition of the carbonate and sulphate of ammonia. Carbonate of ammonia undergoes a change in its composition with every change of its temperature: on being heated, it gives out carbonic acid, and when cooled absorbs it again; when passed through a tube, heated red, it is decompounded into water, charcoal, nitrogen, and hydro-carbonate. Sulphate of ammonia, the partial decomposition of which was discovered by Mr. Hatchet, when sent through a tube heated red, is decompounded into sulphur, water, and nitrogen.

OBSERVATIONS

ON THE

APPEARANCES PRODUCED BY THE COLLISION OF STEEL WITH HARD BODIES.*

1. Mr. Hawksbee long ago showed that no sparks could be produced by the collision of flint and steel in the exhausted receiver of an air-pump; and that in this case a faint light only was perceived. And, since his time, the same observation has been very often made.

The development of the theory of combustion has clearly shown that the vivid sparks obtained from steel in the atmosphere, are owing to the combination of the small abraded and heated metallic particles with oxygen. But it has been a matter of doubt, whether, in the experiment made in vacuo, the faint luminous appearance is owing wholly to the light produced by the fracture and abrasion of the parts of the flint, or only partly to this cause, and partly to the ignition of the minute filaments separated from the steel.

2. I have often found that when a fine and thin flint, which may be easily broken, is used for the collision in vacuo, the light is much more vivid than when a thick and strong one is employed; and, with a strong flint, but just sharp enough to give sparks with steel in the atmosphere, it is seldom that any light at all is produced in the exhausted receiver. These facts seem to

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* [This paper, on the same subject as the preceding, written two years after, was inserted in the Journals of the Royal Institution, published in 1802. It seems advisable to introduce it in sequence, as a practical example of the detection and correction of error by experimental research.]

shew that the abraded particles of steel are not rendered at all luminous by collision, except in consequence of combustion; and the opinion is almost fully proved by the following experiment, which was made in the course of a lecture on the properties of light, in the theatre of the Royal Institution, and which has been since often repeated.

3. A thin piece of iron pyrites,* (sulphuret of iron,) was inserted in a gun-lock in the place of the flint. It gave by collision in the atmosphere very vivid sparks, which were chiefly white, from the combustion of the particles of the steel; but sometimes mixed with a few red sparks from the combustion of the particles of the pyrites. The gun-lock was introduced under the receiver of an air-pump, and the exhaustion was made till the mercury in the short gage stood at about $\frac{6}{10}$ of an inch. The lock was then snapped; but no light whatever was perceived; and the phenomenon was uniform, every precaution being taken to render the room dark, and to preserve the apparatus in order.

4. It is well known that in common cases the finest steel wire does not burn with a white light or sparks in the atmosphere, unless it have been previously heated to a degree much above that of the red heat; it consequently at first view appears extraordinary, that the particles separated from the gun-lock should be heated so as to burn vividly in air; and yet not so as to appear ignited in vacuo; for it is not easy to conceive that they emit light, which from the minuteness of their volume cannot be perceived; or to suppose that the opacity of

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* The etymology of the name of this substance shows that its property of giving fire by collision was very anciently known. It was used in the old gun-locks, with the revolving wheel, for inflaming the priming.

the metallic substances should hinder light generated at their points of contact from being visible. I had formerly supposed, in reasoning upon the phænomenon of the collision of flint and steel, that heat and light might in common instances be only accidentally coexistent; and that in certain cases very high temperatures might be produced without causing the appearance of light. At present, however, I am inclined to believe that the phænomenon may be adequately accounted for upon principles that coincide with the common facts relating to the production and communication of heat.

Mr. Stoddart* has shown, that when steel is gradually heated, it begins to change colour at about 430° Fahrenheit. And this change of colour is occasioned by its combination with oxygen, and as there is every reason to believe, must be connected with the evolution of heat. At about 600°, a temperature much below that of ignition, it oxydates rapidly, and becomes covered with a bluish grey coating. And though in these cases of oxydation the heat evolved at the surface of the metal is not sufficient to raise the temperature of steel wire or of steel plate, so as to cause it to enter into the vivid combustion; yet in acting upon such a minute filament as that struck off in the gun-lock, it may be sufficient to keep up the process of oxydation till it becomes so vivid as to occasion the strongest heat and light. Besides, the surface of this filament is very great as compared with its bulk, and the oxyde produced upon it is less likely to form a coat which might defend the interior parts from the action of the air.

It would not be difficult to find many analogous instances in which the progress of oxydation is dependent upon the mass of the combustible body, or rather upon the relation of this mass to surface: thus, a very thin and small bit of phosphorus will inflame spontaneously, and burn with the vivid light, when wrapped up in filaments of fine cotton; whilst a thicker and larger piece will only shine with the feeble blue light; and though a large mass of zinc may be melted in the atmosphere without inflaming, a small and thin shaving will burn vividly long before it is heated to the temperature of fusion.

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* Nicholson's Journal, 4to. vol. iv. p. 130.

5. In considering the general phænomena of the production of heat and light by mechanical means, it is difficult to conceive that any considerable increase of temperature can be produced on a metallic surface by a single collision; for the conducting power of the metals is such as would speedily cause the heat to be communicated to the contiguous parts; and even in the case of the abrasion of minute particles, though the time required for their separation from the mass is to us imperceptible, yet it must be sufficient to enable them to give out to it a portion of their heat.

The bodies that become luminous by being struck or rubbed together in vacuo, or in gases that do not contain oxygen, or under water, such as fluate and carbonate of lime, silicious stones, glass, sugar, and many of the compound salts, are both electrics per se, and phosphorescent substances; so that the flashes they produce are most likely occasioned partly by the electricity excited on their surfaces by the friction, and partly by their phosphorescence, which is generally occasioned by moderate degrees of heat. It is not, however, improbable, in some cases, that by the collision of very hard stony bodies, which are bad conductors of heat, there may be an actual ignition of abraded particles, and the supposition is countenanced by various facts. Mr. T. Wedgwood found that a piece of window-glass, when brought in contact with a revolving wheel of grit, became red hot at its point of friction, and gave off luminous particles which were capable of inflaming gunpowder and hydrogen gas.* And we are informed by a late voyager,† that the natives of Oonalashka light their fires by striking together two pieces of quartz, their surfaces being previously rubbed with native sulphur over dry grass.

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* Phil. Trans. 1792, p. 45.

† Sauer's Account of Billing's Expedition to the Northern Parts of Russia, p. 159.

EXPERIMENTS AND OBSERVATIONS

ON THE

SILEX COMPOSING THE EPIDERMIS, OR EXTERNAL BARK, AND CONTAINED IN OTHER PARTS OF CERTAIN VEGETABLES.*

1. A few days ago Mr. Coates, of Clifton, informed me that his son, accidentally rubbing two pieces of bonnet-cane together in the dark, had perceived a luminous appearance. This phænomenon was sufficiently novel and curious to induce me to examine it. I found that all canes of this kind, when briskly rubbed together, produced sparks of white light. The luminous appearance was much more vivid on collision. When the canes were violently struck together, sparks, nearly as vivid as those from the gun-lock, were produced: at the same time a strong smell, similar to that generated by the collision of flint, or the excitement of the electric fluid, was perceived.

2. I first thought that the phænomenon was electric, and depended on some resinous matter in the cane: the electrometer, however, was not sensibly affected during the experiment. When the cane was struck against wood of any kind, no light was perceived. When a cane was struck violently against quartz, agate, or any silicious stone, the light was as brilliant as when two canes were struck together. The luminous appearance was produced when sharp steel was struck against the cane. When the cane was struck against sulphate of strontian, or barytes, or carbonate of lime, no light appeared.

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* [From Nicholson's Journal. 4to. 1800. vol. iii.]

3. These circumstances induced me to suppose that the phænomenon depended on silicious earth in the epidermis, or in the whole of the cane. To determine this, I took off a small quantity of epidermis from one of the canes. It was hard, white, and had something the appearance of pulverised glass. When the epidermis was removed, the canes no longer possessed the property of giving out light on collision.

4. To ascertain with certainty the nature of the epidermis, I obtained from 280 grains of cane twenty-two grains of epidermis: this was exposed in a crucible, to the strong heat of an air-furnace, for half an hour. It had lost three grains, was very white, infusible by the heat of the blow-pipe, and insoluble in any of the mineral acids. Ten grains of it were kept in fusion with caustic potash, in a silver crucible, for a quarter of an hour. The compound was white, and semi-pellucid. It was perfectly soluble in water, without communicating to it any turbidity. When muriatic acid was poured into the aqueous solution, a copious white flocculent precipitate was produced. This precipitate, collected, weighed about nine grains, and had every property of silex.

5. To determine whether the wood and internal bark of the cane contained any silex, I burnt 240 grains, carefully deprived of the epidermis, for an hour. The ashes were perfectly white, and weighed about seven grains. When muriatic acid was poured upon them, a portion was dissolved with effervescence. This portion was chiefly carbonate of potash: the insoluble part collected weighed about two grains, and was apparently silex.

6. Having ascertained, by these experiments, that the epidermis of the bonnet-cane was chiefly composed

of flint, and that the luminous appearance above mentioned depended on this composition, I thought it probable that the other canes, particularly the sugar-cane, *arundo saccharifera*, and the bamboo, or *arundo indica*, were similar in their organization. When two bamboos were struck together, I could perceive no luminous appearance. Four ounces of this cane only afforded seven grains of true epidermis. This, exposed to a strong heat, left five grains of white matter, which had all the properties of flint. The reason why these canes produce no light on collision, is, that the flint of the epidermis is too small in quantity, and too thinly diffused. The epidermis of the sugar-cane contained a still smaller proportion of flint: 200 grains of this gave five grains of white ashes, of which only one grain was soluble in muriatic acid: the four grains of soluble matter appeared to be carbonate of lime. A large piece of bamboo (the weight of which I am ignorant of), deprived of the epidermis, gave a considerable quantity of white ashes, of which about two-thirds were soluble in the muriatic acid: the insoluble part was silex. The ashes of the sugar-cane, deprived of the epidermis, appeared to be chiefly composed of carbonate of lime and carbonate of potash.

7. The analogy between the English reeds and grasses, and the canes, and particularly the similarity of the appearance of the epidermis, induced me to suppose that they might likewise contain silex. On this supposition, I first examined the *arundo phragmites*, or common reed. It produced no luminous appearance on collision with flint. Twenty-seven grains of the epidermis, exposed to a strong heat, gave thirteen grains of white earthy matter, insoluble in the mineral acids. Ten grains of this were fused with thirty-four grains of

potash: the compound was soluble in water. The nitrous acid threw down from the aqueous solution a white flocculent matter, which was necessarily flint: this matter I did not weigh, but I conjecture that it was about seven or eight grains. One hundred and ten grains of the reed from whence the epidermis was removed gave about six grains of flint.

8. I now examined the culm of wheat: 200 grains burnt gave thirty-one grains of white ashes; of these eighteen grains were soluble with effervescence in the muriatic acid: the remainder had all the properties of silex. The matter dissolved in the muriatic acid was potash. The ashes of oats and barley afforded silex in nearly the same quantities as those of wheat. The culms of the grasses, among which I examined *anthroxanthum*, *poa pratensis*, and some others, appeared to contain more silex in the epidermis than even the corns, with a much larger proportion of carbonate of potash.

9. The silex in all these vegetables, as in the canes, appeared to be contained in the epidermis, or in the second bark. When the plants are carefully burnt, the figure of the epidermis is preserved. In the cane, when well burnt, it has a white glossy appearance, and is semi-transparent. In the reeds, corns, and grasses it is white and opaque, and, when viewed through a magnifier, appears to consist of longitudinal threads joined together by net-work: in the microscope, even the smallest particles have a distinct reticular appearance.

10. The quantity of carbonate of potash in the ashes of the corns and grasses, induced me to suppose that, in a strong heat, they might be fused into glass. The ashes of the *arundo phragmites* were exposed to the strongest heat of an air-furnace for some minutes; there

was no appearance of fusion; the carbonate of potash was not sufficient to form glass with the siliceous earth. The ashes of straw, in a strong heat, gave a fine white transparent glass, perfectly insoluble in water and indecomposable by acids. The ashes of hay gave a black glass, with a superabundance of potash. This conversion of corn and grass into glass, may be effected by the blowpipe, and affords a pleasing experiment. A straw burnt with the blowpipe, and urged with the strong heat of the blue flame, beginning at the top, is converted into a fine pellucid globule of glass almost fit for microscopic experiments. A culm of grass is fused under the blowpipe into a globule of glass, black and opaque, probably from its containing iron.

11. These facts will afford some curious inferences to the speculator on organized nature. The flint entering into the composition of these hollow vegetables, may be considered as analogous to the bones of animals; it gives to them stability and form, and by being situated in the epidermis, more effectually preserves their vessels from external injury. They will probably enable us to determine whether silex be a simple or compound substance. Reed or wheat might be easily made to vegetate deprived of silex. Confined under mercury, in a soil composed of known quantities of the saline earths, and supplied with distilled water and factitious air, we might discover whether it would compose silex, or substitute for it another earth. This experiment, as well as some others on the same subject I propose to make, if leisure and opportunity occur. The numerous complex attractions of organic beings, resulting from their variety of composition, are continually producing changes which the art of the chemist is unable to imitate. Though the chemist, at present, can extend

his power no further by the simple attractions and repulsive motions of inorganic matter, yet a path of science, displaying a boundless field for investigation, seems now open in the changes effected in dead matter by living beings. By discovering these changes, we might go far towards discovering the laws of their organization.

AN ACCOUNT OF SOME EXPERIMENTS

MADE WITH THE

GALVANIC APPARATUS OF SIGNOR VOLTA.*

In pursuing a course of experiments on the galvanic influence, I have made some new observations. They are connected with the curious facts already detailed in Mr. Nicholson's Philosophical Journal,† and they may possibly lead to elucidations of the phænomena.

The apparatus that I employed was constructed for Dr. Beddoes, and never consisted of less than 110 pairs of metallic plates. I found the sensible galvanic shock very much increased when the parts communicating with the conductors were moistened with solution of green sulphate of iron. A pile erected with pieces of cloth, wetted in that substance, acted rather more intensely than a similar pile erected in the usual mode. It, however, lost its powers in a shorter time: perhaps a solution of the sulphate of zinc may be employed with advantage.

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* [From Nicholson's Journal, 4to. vol. iv.—Sept. 1800.]

† [An account of Volta's great discovery of the galvanic pile; the decomposition of water by means of it by Messrs. Nicholson and Carlisle, and other chemical effects first observed by Mr. Cruickshank and Dr. Henry.

Volta's first letter announcing his memorable discovery of the pile was dated from Como, March 20, 1800; on the 30th of the following month, the first pile ever constructed in this country was tried by Messrs. Nicholson and Carlisle; and on the 2nd of May, the decomposition of water by it and the separation of its elements apart and at a distance was observed by them, which was the foundation of electro-chemistry. This most important fact was published in Nicholson's Journal for July of the same year, and appeared before Volta's own account of the voltaic pile, which was read to the Royal Society on the 26th of June, and was inserted in the second part of the Philosophical Transactions for that year. The zeal with which voltaic electricity was immediately cultivated in this country, was very remarkable, and indicative of a very sagacious appreciation of its vast importance.]

a. Struck with the curious phænomena noticed by Messrs. Nicholson and Carlisle,* namely, the apparent separate production of oxygen and hydrogen from different wires, or from different parts of the water completing the galvanic circle, my first researches were directed towards ascertaining if oxygen and hydrogen could be separately produced from quantities of water not immediately in contact with each other.

Two silver wires, one from the zinc end of the apparatus, and the other from the silver end, were made to communicate with two glasses, distant from each other about five inches, and filled with water that had been long boiled, and was yet warm. Into one of these glasses I dipped the fingers of my right hand, and into the other the fingers of my left, so that the communication between them was made through my body. Immediately after the shock, the zinc wire † began to calcine very fast, white clouds diffusing themselves from it through the water. At the same time gas was formed round and extricated from the silver wire in the other glass. The communication was kept up for half an hour; during this time no gas was produced from the zinc wire, which continued to calcine throughout the process. The gas from the silver wire was caught in a small inverted cylinder; examined by the test of nitrous gas, it appeared to contain no oxygen, and inflamed with twice its bulk of common air, gave such a diminution, as denoted it to be hydrogen nearly pure.

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* Philos. Journal, p. 183, vol. iv.

† To prevent unnecessary repetitions, after Mr. Cruickshank, I have called the wire connected with the zinc end of the apparatus, the zinc wire, and that connected with the silver end, the silver wire.

This apparatus being adjusted as before, the communication between the glasses was made through three persons; the process went on, though less rapidly; the oxygen was fixed as before by the silver in one vessel, whilst the hydrogen was given out in the other. When muscular fibre, living vegetable fibre, or a moistened thread not exceeding three feet in length, was employed as the medium of connection between the glasses, similar effects were produced, though the gas was evolved more slowly than when the living animal was the connector. Muscular fibre appeared to be a better conductor than vegetable fibre, and vegetable fibre a better conductor than the moistened thread.

b. Several glass tubes about one-third of an inch in diameter, and four inches long, having each a piece of gold wire inserted into one end, hermetically sealed, and the other end open, were provided. Two of these tubes were filled with distilled water and inserted into separate glasses filled with that fluid. The glasses were made to communicate by means of fresh muscular fibre; the gold wires were connected with the machine by means of silver wires; one end with the silver end, the other end with the zinc end. Gas was immediately given out from both the gold wires; but most rapidly from that connected with the silver. In four hours and a quarter the process finished; the water in the tube communicating with the silver being below the gold wire. The gases were examined; the quantity from the water communicating with the zinc was equal to thirty-three grain measures, that from the water connected with the silver to nearly sixty-five grain measures. The zinc gas was mingled with eighty measures of nitrous gas, containing $\frac{1}{22}$ nitrogen; a rapid dimunition took place, and when the residuum was exposed to solution of green muriate of iron,* not quite five measures remained. Hence the thirty-three measures of gas evidently contained more than thirty-one measures of oxygen. The sixty-one measures in the other tube, gave with nitrous gas a dimunition barely perceptible, and fired after the absorption of the nitrous gas by the electric spark, with sixty measures of oxygen, left a residuum nearly equal to thirty-six measures; hence the gas was hydrogen almost pure.

c. There was every reason to suppose, that the slight dimunition produced by the mixture of the hydrogen with nitrous gas in the last experiment, as well as the residual gas of the oxygen, were owing to common air held in solution by the distilled water, and given out from it during the process. To ascertain if the gases could be obtained perfectly pure, when water deprived of its loosely combined air by boiling was employed,—the two tubes were filled with water that had been boiled for more than eight hours, and that was yet so hot as to be painful to the fingers; the glasses were filled with water of the same kind, and the process conducted as before; the tubes being suffered to cool before the communication was made, gas was given out very rapidly from the water connected with the silver; but very slowly with that connected with the zinc. During the whole of the process, no globules of air formed on the sides of tubes, as in the last experiment. In five hours the tube connected with the silver contained fifty-six grain measures of gas. That connected with the zinc contained only fourteen measures. The fifty-six measures gave no dimunition with nitrous gas, and appeared by the test of detonation, to be pure hydrogen. The fourteen measures tried by the tests mentioned in the last experiment, appeared to be oxygen, mingled with no perceptible quantity of other gas. In this experiment, as in the last, the gold wires were not apparently acted upon, nor was their colour in the slightest degree altered; the deficient proportion of oxygen, there was every reason to believe, was owing to the absorption of that gas in the nascent state by the boiled water. Boiled water was now exposed to, and agitated in oxygen over mercury, till it was judged to be saturated with that gas. The tube connected with the zinc was filled with this water; the other tube was filled with common boiled water. The galvanic process was continued seven hours. In this time the water connected with the zinc had given out twenty-seven grain measures of oxygen apparently pure; from the water connected with the silver, fifty-seven measures of hydrogen had been extricated.

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* Solution of green muriate of iron speedily absorbs nitrous gas, without effecting any change in it at common temperatures, and it is possessed of no action on gases not absorbable by water and incapable of supporting flame. Solution of green sulphate of iron, likewise absorbs nitrous gas without decomposing it.

d. Having thus ascertained that oxygen and hydrogen, nearly in the proportions required to form water, could be separately produced from quantities of water, having no communication with each other, except by means of the dry metallic conductors and muscular fibre; I next endeavoured to ascertain, if the contact of the metallic wires, with the metallic plates of the apparatus were essential to the effect. The conducting ends, i. e. the silver and zinc, were made to communicate with two glasses of water, by means of two unconnected pieces of muscular fibre. A piece of silver wire was made the medium of connection between the glasses. Immediately after the connection, I was surprised by seeing that end of the wire in the water communicating with the silver calcining; whilst gas was given out from that part of it in the vessel communicating with the zinc; as was the case in the broken circuit described by Mr. Nicholson. When the tubes with gold wires, connected by silver wires, were employed, oxygen was given out in the water connected with the silver, and hydrogen in that communicating with the zinc. In none of these experiments could any production of gas from the muscular fibre be perceived; but the parts exposed to the water became whiter than before.

When (the glasses being connected with the apparatus by muscular fibre) the communication between them was made through my body by means of the gold wires in the tubes; one being in contact externally with my right-hand, the other with my left, oxygen was produced as before in the glass connected with the silver, and hydrogen in that connected with the zinc. When I made the communication, holding a silver wire partly plunged into the water connected with the silver, in my right-hand, the fingers of my left-hand being in the other glass, the silver wire became slowly oxydated, and no gas was perceptibly given out in either of the glasses. When, on the contrary, I introduced my hand into the silver glass, and the wire into the zinc glass, gas was given out round the wire, no oxydation took place, and no gas was extricated in the silver glass.

When the glasses were made to communicate both with the machine and with each other, by means of muscular or vegetable fibre; and metallic wires introduced into either or both of the glasses, and wholly or partially covered with water, no gas was given out from them, and no apparent chemical change took place.

Reasoning on this separate production of oxygen and hydrogen, from different quantities of water, and on the experiments of Mr. Henry, jun., on the action of galvanic electricity on different compound bodies,* I was led to suppose, that the constituent parts of such bodies (supposing them immediately decomposable by the galvanic influence) might be separately extricated from the wires, and in consequence obtained distinct from each other.

a. I filled two of the small tubes mentioned in *b.* 1. with strong solution of caustic potash, and inverted each of them in a glass filled with the same substance; the glasses were made to communicate with each other by means of muscular fibre, and the gold wires in the tubes connected with the ends of the pile. Gas was produced much more rapidly in this process from both wires, than in the experiment with simple water. In three hours no deposition had taken place in either of the glasses, nor were the gold wires sensibly acted upon. The gas given out in the tube connected with the zinc, measured exactly 37 grain measures, and proved to be oxygen absolutely pure, for with 80 measures of nitrous gas, containing about $\frac{1}{36}$ nitrogen, it diminished to less than 3 measures. The gas given out in the tube connected with the silver, was equal to rather more than 72 grain measures.

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* Phil. Journal, vol. iv. p. 224.

It gave no diminution with nitrous gas, and 20 grain measures of it, fired with rather more than one 20 grain measures of oxygen, containing about ·06 nitrogen, left a globule of air hardly perceptible.

Surprised at these results, which proved that no decomposition of potash* had taken place, and that that substance in this mode of operating only enabled the galvanic influence to extricate oxygen and hydrogen more rapidly from water, I was induced to operate upon this substance in the way of direct communication. The gold wires were passed through holes in the side of a small glass tube closed at one end, and connected so as to be distant about the eighth of an inch. This tube was filled with solution of potash, and inverted in glass filled with the same substance; the gold wires were made to communicate with the ends of the pile. Gas was produced rapidly from both wires, but most from the silver wire; the gold was not acted upon, and no deposition took place. When near a quarter of a cubic inch of gas had been collected, it was transferred to a detonating tube, and, fired by the electric shock over mercury, it gave a vivid inflammation, and left a globule of air not equal to $\frac{1}{80}$ of the whole quantity.

b. Solutions of caustic ammoniac were exposed to the galvanic influence in the two tubes with gold wire and connected by muscular fibre. Gas was given out very slowly in the tube connected with the zinc, and the gold wire was evidently acted upon, being in some parts corroded, and in other parts covered by a yellowish deposit. In the tube connected with the silver, gas was given out more rapidly, and the gold was not altered in appearance. In five hours the gas in the zinc tube was equal to 5 measures, and proved to be a mixture of nearly 3 of oxygen and 2 of nitrogen. The gas in the silver tube measured 31 grains, and appeared to be hydrogen, mingled with a minute quantity of nitrogen. I repeated this experiment several times, to ascertain if, after the solution of ammoniac had been long galvanized, the proportion between the gases would be different. The gas given out in the zinc tube was always to that in the silver tube nearly as 1 to 6, but the quantity of oxygen appeared to increase towards the end of the process. A quantity of solution of ammoniac, the same as that used in the experiment exposed to heat in a mode described in Research. Chem. and Phil.* readily produced $\frac{1}{20}$ of its bulk of unabsorbable gas, which gave no diminution with nitrous gas, and appeared to be nitrogen. In every experiment yellow deposit was formed upon the gold in the zinc tube; muriatic acid poured upon some of the yellow deposit slowly dissolved it, a little nitrogen being given out during the solution.

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* [Dr. Henry (then Mr. Henry), from his first experiments, inferred that hydrogen was a constituent part of potash,—and that besides, it is probably composed of azote and carbon. He was led into error on the subject by using mercury, as he himself stated in the same volume of Nicholson's Journal. To him belongs, amongst many other merits as a Chemical Philosopher, the no inconsiderable one of being one of the first who employed galvanism as an agent of chemical analysis; Mr. Cruickshank alone preceded him. Had he prosecuted his early galvanic inquiries, it cannot be doubted that with his ability and ingenuity in research, he would have made many happy and brilliant discoveries.]

When a solution of caustic ammoniac was exposed in the silver tube, and water in the zinc tube, the gold wires were not perceptibly altered, and oxygen was given out in the zinc tube and hydrogen in the silver tube, namely, in the proportions required to produce water. When, on the contrary, water was connected with the silver, and solution of ammoniac with the zinc, hydrogen was produced from the water; the zinc gold wire was corroded, and the mixture of oxygen and nitrogen to the hydrogen as six to one (one to six?) was produced as before.

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* [Res. ii. D. i. s. 2.]

c. Concentrated sulphuric acid was galvanized in the double tubes connected by muscular fibre. The gold wire in the zinc tube was not dissolved or corroded, and in a great length of time 41 measures of gas, which proved to be pure oxygen, were given out from it. But little gas was given out in the silver tube; the acid in it was clouded with a white substance, which was evidently sulphur; it was perpetually produced round the point of the wire: 15 measures of gas were evolved, which gave rather greater diminution, fired with oxygen, than pure hydrogen; hence, they might possibly have been partially sulphuretted hydrogen.

When solution of caustic potash was put into the silver tube, and sulphuric acid into the zinc tube, pure hydrogen was disengaged in the silver tube, and pure oxygen in the zinc tube; the same phænomena took place when water was employed instead of solution of potash.

When water was connected with the zinc, and sulphuric acid with the silver, the products were the same as when pure sulphuric acid was used in both tubes. When very dilute sulphuric acid was employed in both tubes, oxygen and hydrogen nearly in the proportions required to form water, were separately evolved.

d. The tubes were filled with pure solution of muriatic acid, and the communication made as before. No gas was given out in the zinc tube, and the gold in it was very much corroded: 30 measures of pure hydrogen were collected in the silver tube, the gold in which was not perceptibly acted upon. When water was made to communicate with the zinc, and muriatic acid with the silver, neither of the gold wires was acted upon; and 22 measures of oxygen were collected from the water, and 41 of hydrogen from the muriatic acid. When water was connected with the silver, and muriatic acid with the zinc, the same phænomena took place, as when pure muriatic acid was used in both tubes.

e. Concentrated solutions of nitric acid were galvanised in the tubes,—19 measures of pure oxygen were produced in the zinc tube. A globule of gas only, not equal to half a measure, was produced in the silver tube, and the acid became green on the top. The globule of gas did not diminish with oxygen; it was too small to be tried by other tests. The gold wires were not acted upon.

When nitric acid was connected with the zinc, and water with the silver, oxygen and hydrogen were separately produced. When water was connected with the zinc, and nitric acid with the silver, oxygen was given out from the water; no gas was given out from the acid, and it became green.

In the experiments on the sulphuric and nitric acids, it is most probable that the acids were decomposed by the nascent hydrogen in the silver tube. In the experiments on the muriatic acid and ammoniac, the deficiency of the oxygen in the gold tube most probably partly arose from the oxydation of the gold, in consequence of what may be called predisposing affinity. In these processes, none of the compound bodies appear to have been immediately decomposed by the galvanic influence.

The difference between my results and those of Mr. Henry, may be accounted for from the difference between our modes of operating. I suspect, however, that on repeating his experiments on the solution of potash under new circumstances, that ingenious chemist will find reasons for altering his conclusions with regard to the decomposition of the alkali.* Judging from the rapidity with which the gases were extricated, solution of potash would seem to be a better conductor than water,—water a better conductor than solution of ammoniac, and a solution of ammoniac better than either of the three mineral acids. Possibly, phosphoric acid, and other acids, may be decomposed when exposed to nascent hydrogen, produced under the galvanic influence. If the ratio between the quantities of the oxygen and hydrogen produced from the different wires be always the same, whatever substances are held in solution by the water connected with them, this nascent hydrogen will become a powerful and accurate instrument of analysis.

ADDITIONAL EXPERIMENTS ON GALVANIC ELECTRICITY, IN A LETTER TO MR. NICHOLSON.† OCT. 1800.

SIR,

The earlier experimentors‡ on animal electricity noticed the power of well-burned charcoal to conduct the common galvanic influence.

I have found that this substance possesses the same properties as metallic bodies in producing the shock and

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[* Vide Note, p. 146.]

[† From Nicholson's Journal, vol. iv. Oct. 1800.]

‡ The inventor of the galvanic pile discovered the conducting power of charcoal. His experiments were confirmed by Creve and Schmuck. See Paff on Animal Electricity, p. 48.

spark,* when made a medium of communication between the ends of the galvanic pile of Signor Volta. I have likewise found that perfectly well-made charcoal, when connected with water or aqueous solutions in the galvanic circuit, effects changes in them analogous to those produced by metals; but connected with peculiar appearances.

1. Two long and thin slips of dry charcoal were connected with silver wires attached to the ends of a galvanic pile of 60 pieces. The points of the charcoal slips were immersed in a glass of water, at the distance of half an inch from each other; and the globules of air adhering to them being carefully removed, the communication was made sure.

In about a minute, particles of gas began to form and evolve themselves round the point of the charcoal connected with the silver side of the apparatus. Near a quarter of an hour elapsed before any gas was produced from the zinc side; the gas that was produced adhered to the charcoal in large globules, and did not pass through the water. As long as the communication was kept up, the silver charcoal gave out gas very rapidly.

2. Reasoning from the common phænomena of the action of red hot charcoal on water, and on the analogous galvanic facts, it was reasonable to conclude that the gas evolved from the charcoal on the silver side of the apparatus was hydro-carbonate, and that carbonic acid had been produced on the zinc side, which had been chiefly absorbed by the water.

To ascertain if this conclusion was true, two small open tubes, about one-fourth of an inch in diameter, and three inches long, were provided. Into one end of each of them a thin piece of hard and polished charcoal was introduced and fastened by cement. They were then filled with distilled water, and inverted in a glass containing that fluid; the tops of the pieces of charcoal being made to communicate with the ends of a pile.

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* The spark is most vivid when the charcoal is hot.

The process was carried on for more than fourteen hours; at the end of which time the quantity of gas produced from the charcoal on the silver side was at least fifty times greater than that produced on the zinc side. The tube from the zinc side, with its water and gas, was introduced into a vessel of lime water. On agitation the water became clouded, but the gas was not perceptibly diminished: mingled with twice its bulk of nitrous gas, it gave such an absorption as denoted that it contained nearly the same quantity of oxygen as common air. The gas produced from the silver side of the pile did not at all diminish with nitrous gas; twelve measures of it, mingled with eight measures of oxygen, in a detonating tube, and acted on by the electric spark, inflamed, and left a residuum equal to rather more than three measures. Lime water introduced to these became a little clouded, and a slight absorption took place. After this absorption, at least two measures and a quarter of gas remained, which, mingled with nitrous gas, gave red fumes and diminution. Hence they evidently contained oxygen.

3. Surprised at these results, from which it appeared that the gas from the silver side of the apparatus held very little charcoal in solution, and required nearly the same quantity of oxygen to destroy it as the inflammable air from the metals, I repeated the experiment, making use of water that had been long boiled, and was yet warm. In this case no gas was given out from the zinc side during the whole of the process, and more

than half an hour elapsed before any was produced from the silver side. What was produced, however, gave nearly the same diminution, when fired with oxygen, as common inflammable air, and the residuum produced but a slight precipitate admitted to lime water.

It was easy to account for the deficiency of gas on the zinc side in this process, by supposing that the gas produced in the former experiment was air previously dissolved by the distilled water, and liberated in consequence of the stronger attraction of carbonic acid for that fluid; but as I had before found that in the common galvanic process with the metals, the hydrogen was immediately evolved even in boiled water, it was difficult to conceive why such a length of time was required for the production of the inflammable gas. When I introduced charcoal connected with the zinc side, and silver wire connected with the silver side, into boiled water, gas was almost immediately given out from the wire, though when I connected silver with the zinc side, and charcoal with the silver side, no gas was liberated for many minutes.

4. A slip of charcoal was connected with the zinc end, and a silver wire with the silver end, and both plunged into a vessel of lime water. Gas was immediately given out from the silver wire; a few globules only formed round the charcoal: they were apparently covered with a white crust. As the process advanced, white clouds fell from the charcoal, and diffused themselves through the fluid.

5. Two pieces of charcoal were connected with the ends of the pile and plunged into a strong solution of caustic potash. During two hours no gas was given out from either of the pieces, and no change of colour was perceived in the fluid, though the communication

was perfect. When a silver wire was connected with the zinc, and charcoal with the silver, gas was produced from the wire, but none from the charcoal. When charcoal was connected with the zinc, and silver wire with the silver, gas was very rapidly produced round the point of the wire; but not an atom formed round the charcoal.

6. When slips of charcoal connected with the pile were introduced into solution of ammoniac, gas was given out from the zinc charcoal; but none from the silver charcoal. When silver wire was connected with the silver side, the charcoal being still connected with the zinc side, gas was given out from both, but most rapidly from the wire. These gases were caught and examined. That from the charcoal gave no diminution with nitrous gas. An accident prevented me from examining it by other tests; the gas from the silver equalled twenty times the volume of the other gas, and appeared to be pure hydrogen.

I shall at present offer no theoretical conjectures concerning these experiments. The two last will probably lead to interesting conclusions. I am, at this moment, engaged in examining small quantities of solution of potash and ammoniac, which have been long galvanized in contact with charcoal: the result of this examination, if at all important, I shall take the liberty of communicating to you at some future time.

I remain, &c.

(Signed) HUMPHRY DAVY.

Dowry Square, Hotwells, Sept. 22, 1800.

NOTICE OF SOME OBSERVATIONS ON THE CAUSES OF THE GALVANIC PHÆNOMENA, AND ON CERTAIN MODES OF INCREASING THE POWERS OF THE GALVANIC PILE OF VOLTA.* Nov. 1800.

The nature of this communication is incompatible with a detail of the opinions prevailing amongst philosophers, respecting the causes of the galvanic phænomena: they have been generally supposed to depend on the different powers of bodies to conduct electric fluid. Fabroni was the first who systematically attempted to prove that they were chemical effects.†

Immediately after I had perused an interesting observation of Lieutenant-Colonel Haldane‡ on the non-excitement of galvanism in the vacuum of an air pump, I began an investigation with the view of ascertaining precisely the influence of the atmosphere on the phænomena. In carrying on this investigation, I have met with some new facts, which are capable of arrangement, and which will probably lead to a complete explanation of the galvanic effects.

The piles that I employed for ascertaining the influence of fictitious airs on the galvanic phænomena, were erected horizontally in the usual mode; but to prevent the plates from separating when in an oblique position, their sides were joined together by resinous cement at two or three points, sufficient interstice being preserved to admit of a free circulation of the air. The gases, when they were produced, were received in small

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[* From Nicholson's Journal, vol. iv. Nov. 1800.]

† Phil. Jour. vol. iii. p. 308.

‡ Idem, vol. iv. p. 242.

tubes filled with distilled water, containing wires covered internally with wax, and communicating with the ends of the pile.* The piles were introduced into the airs through water, and elevated above the water by a metallic plate cemented to their lower extremities.

1. *Zinc, whether connected with silver in single galvanic circles, or constituting the plates of the galvanic pile, seems to undergo no oxydation at common temperatures, as long as the water in contact with it is pure.*

By pure water, is more immediately meant water holding in solution no oxygen gas, no nitrous gas, and no acids. It has long been known that certain metallic bodies," which oxydate slowly in water exposed to the atmosphere, effect no change in pure water.† This I have observed is particularly the case with regard to zinc. That zinc, when in contact with silver in the atmosphere, and forming with it a circuit by means of water, becomes oxydated much more rapidly than when simply in contact with water, was observed by Dr. Ash.‡

Supposing the more rapid oxydation to be the effect of a peculiar electrical influence produced by the contact of the metals, it would be reasonable to conclude, that zinc in single circles with silver and pure water, or at least in the galvanic pile erected with cloths moistened in pure water, would undergo oxydation. Fabroni,§ however, has advanced that simple galvanic circles do not oxydate in water, unless it be exposed to the atmosphere. That the zinc of the galvanic pile does not oxydate in contact with pure water, will appear from the following observations.

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* Before these experiments were made, I had found, by numerous trials, that a pile acted in the atmosphere immediately after immersion in water without being wiped, though more feebly than before: I had likewise found that after the first immersion, the powers were not diminished, by subsequent ones.

† See Fabroni, Phil. Jour. vol. iii. p. 309.

‡ And Humboldt,—see Researches, Chem. and Phil. p. 568.

§ Phil. Jour. vol. iii. p. 309.

a. A small pile of silver and zinc, having its pasteboards moistened with water, that had been just boiled, was introduced into a vessel of water that had been long boiling, and was yet warm. Resinous cement was poured upon the surface of the water, and fastened to the glass as it cooled, to preserve it effectually from the contact of air.* The apparatus after remaining for two days, was examined; the zinc plates were scarcely at all tarnished; no oxyde was deposited in the water, and no gas had been evolved through it. A similar pile, exposed for nearly the same time to water in contact with the atmosphere, had deposited much white oxyde, and given out some gas, and the zinc plates were whitened both internally and externally.†

b. No influence can be communicated from an elastic atmosphere, enabling the zinc of the galvanic pile to decompose pure water; for piles were introduced into hydrogen, nitrogen, nitrous oxyde, and hydro-carbonate, and suffered to remain in them for different lengths of time; but in none of these gases was the zinc more oxydated than if the pile had been immersed in pure water.

c. A galvanic pile was suffered to remain in vacuo for fourteen hours, the gage being about $\frac{9}{10}$, the zinc plates were slightly tarnished, but no white oxyde had formed upon them.

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* Oil of turpentine, and even common oil, as will be seen hereafter, is ineffectual for this purpose.

† The temperature in these experiments was from 54° to 61°. It is impossible to free water of *all* its dissolved air by boiling: it is likewise impossible to prevent a few globules of air from passing through the cement whilst it is cooling: the very slight tarnish of zinc kept in boiled water may be owing to the minute quantities of common air existing in the water from both these causes.

2. *The oxydation of the zinc plates of the Galvanic Pile takes place whenever the water in contact with them holds atmospheric air, or oxygen, or nitrous gas, or nitrous acid, or marine acid, &c., in solution.*

a. The oxydation of the zinc of the pile in the atmosphere, and the protrusion of carbonate of soda, have been accurately described by Messrs. Nicholson and Carlisle. I have found that the phænomena of oxydation take place much more rapidly in pure oxygen than in the atmosphere. I have likewise found that they take place more slowly in nitrous gas than in the atmosphere. That zinc is oxydated in solutions of nitrous and marine acids, is a well known fact.

3. *When the zinc in contact with water, holding in solution substances containing loose oxygen or acids, is oxydated, these substances are altered, or they exert some chemical affinities.*

a. A small galvanic pile, exposed to about twenty-one cubic inches of oxygen gas for six hours, effected a diminution of it which might have equalled one-fourth.

b. A similar pile, exposed to an equal quantity of atmospheric air for two days, diminished it one-sixth: the residuum being suffered to pass into the atmosphere, gave a smell which strongly resembled that of ammoniac; and the pile held over marine acid produced dense white clouds.

In another experiment, an equal quantity of air, exposed to the pile for three days, gave but a very slight diminution with nitrous gas, and could not be inflamed with atmospheric air.

c. I have noticed, Res. Chem. et Phil., that wetted zinc, placed in contact with nitrous gas over mercury, slowly converts it into nitrous oxide of ammonia. A small pile exposed to about twenty-two cubic inches of nitrous gas for three days, diminished it one-fourth, and some of the gas was rendered absorbable by water.

d. The formation of nitrous gas, nitrous oxyde and ammoniac, when very weak solutions of nitrous acid are made to oxydate zinc, demonstrate both the decomposition of the acid and the water.

e. The oxydation of zinc in solutions of marine and sulphuric acids in water, appears to be owing to the affinity which has been called predisposing.

4. *The galvanic pile of Signor Volta seems incapable of acting when the water between the pairs of plates is pure.*

The word *pure* is here used in the same sense as in 1.

a. I have found by numerous experiments, that the galvanic pile introduced into hydrogen, through common water, ceases to evolve gas in the tube, and to act in about five or six minutes, *i. e.* in about the time required to consume the atmospheric air dissolved in the common water between its plates. The action of a pile, as known by its power of evolving gases from water, is diminished immediately on its introduction into these gases. It ceases in them nearly in the same time, and cannot be restored by admitting fresh gases of the same kind, though, as will be seen in the next section, it is immediately restored by immersing the pile for a moment in water saturated with atmospheric air.

b. I have found by numerous experiments, made with the assistance of my friend, Mr. King, that the galvanic pile ceases to act in vacuo when the gage is at about $\frac{6}{10}$ of an inch, even though the poles are connected by wires with the atmosphere, and the water it is made to act upon in contact with the atmosphere.

5. *The Pile acts when the water between the double plates holds in solution atmospheric air, or oxygen, or nitrous gas, or nitrous acid, or marine acid.*

This fact I have proved by numerous experiments.—*a.* A pile acted in atmospheric air, included in a glass cylinder over water for two days, till nearly all the oxygen of the air was consumed.—*b.* A pile decomposed water much more rapidly in oxygen than in common air, and less rapidly in nitrous gas than in common air.—*c.* That the influence of an elastic oxygenated atmosphere is not essential to the galvanic effects, is evident from the fact of the constant restoration of the powers of a pile after they had ceased to appear in the hydrogen, nitrogen, &c., by momentary immersion in water saturated with atmospheric air. In these experiments the piles were plunged into the water confining the gases, and again immediately elevated into the gas without being exposed to the atmosphere, and the phænomenon could be owing to no other cause than the impregnation of the water with atmospheric air, because when piles were plunged into water saturated with nitrous oxyde,* their powers were not restored.—*d.* I have proved by many experiments † that water, deprived of air, is capable of attracting it from the spirits of turpentine, when the last is in contact with the atmosphere. The galvanic pile acts in spirits of turpentine for a greater length of time, and nearly as well as in the atmosphere, the water between its plates being constantly supplied with air from the spirits. It acts but for a short time in spirits of wine, on account of the combination of this fluid with its water.—*e*. After a pile has ceased to act in hydrogen, its powers were uniformly restored by a momentary immersion in very diluted marine acid. They were likewise restored, and rendered more intense than in the atmosphere by momentary immersion of the pile in dilute nitrous acid, though they continued to be exerted for a short time only, i. e., till the acid was decomposed or saturated.

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* This gas expels much common air from water. See Res. Chem. et Phil. R. ii. 3. 1.

† These experiments will be hereafter detailed.

6. *The power of action of the pile of Volta appears to be, in great measure, proportional to the power of the conducting fluid substance between the double plates to oxydate the zinc.*

This seems sufficiently proved from the facts in the following sections. The zinc oxydates less rapidly in nitrous gas than in atmospheric air, and less rapidly in atmospheric air than in oxygen: and the power of action of the pile as known by its evolving gas from water is greater in oxygen than in atmospheric air, and greater in atmospheric air than in nitrous gas. The power of the pile to decompose water, and to give the shock is wonderfully increased after it has been dipped in marine acid, and still more increased after it has been dipped in weak nitrous acid; and these bodies only enable the zinc to oxydate itself more rapidly. A series of plates, in which the oxydating conducting fluid was strong nitrous acid, acted, as will be seen hereafter, infinitely more powerfully than any other combination; so that it would seem that the power of a pile is not much connected with the evolution of hydrogen from water.

7. *Conclusions.*—Of two phenomena, or of two series of phenomena, we can only affirm that the one is the

cause of the other when it uniformly precedes it, and when their modifications are connected. But it appears from all the foregoing facts, that the galvanic pile of Volta acts only when the conducting substance between the plates is capable of oxydating the zinc; and that in proportion as a greater quantity of oxygen enters into combination with the zinc, in a given time, so in proportion is the power of the pile to decompose water, and to give the shock greater. It seems, therefore, reasonable to conclude, though with our present quantity of facts we are unable to explain the exact mode of operation, that the oxydation of the zinc in the pile, and the chemical changes connected with it are *somehow* the cause of the electrical effects it produces.

8. *Of a new mode of constructing a Pile.*

Assuming the truth of this conclusion, it was easy to conceive, that a pile much more powerful than any hitherto constructed might be made, particularly supposing that the decomposition of water was not essential to the process. Plates of zinc and silver, 1·2 inches square, were fastened in pairs by resinous cement: eighteen of these pairs were connected to each other by cement, and so inclosed by it as to leave water-tight partitions open at one side only between each pair of plates. When muriatic acid was poured between the partitions of this machine, the plates being perpendicular, it acted very powerfully; its capability of decomposing water and giving the shock, being at least equal to that of a common pile of seventy plates. Diluted nitrous acid made it act still more powerfully. When the partitions were filled with water, its action was barely perceptible. Concentrated nitrous acid was poured into them. In this case the first shock was so powerful as to benumb my fingers for some seconds, and I did not dare to take another. I was almost immediately obliged to throw the pile into water to prevent it from being destroyed, so that there was no time to ascertain its power of decomposing water.

In a second experiment, with strong nitrous acid, I used only five pairs of plates, when the shock was full as powerful as from the common pile of thirty plates.

Three pairs of plates, with nitrous acid, gave a very sensible shock.

I have procured (on account of the loss of the silver where this substance is part of the pile with nitrous acid) a number of plates of copper, iron, and zinc. They have not yet been disposed in the apparatus; but I expect by means of nitrous acid, to produce effects from them equal to those of the strongest electrical battery.

EXTRACT OF A LETTER TO MR. NICHOLSON, DATED OCT. 23, 1800, SUPPLEMENTARY TO THE PRECEDING PAPER ON GALVANISM.*

WHEN I exhibited to Dr. Beddoes the phænomenon of the renovation of the powers of the galvanic pile, after it had ceased to act in hydrogen, nitrogen, &c. by momentary immersion in water, holding in solution atmospheric air, he requested me to try whether oxygenated muriatic acid gas, solution of nitre, &c. would not increase the effects. The fear of destroying the silver prevented me at the time from trying the experiment on oxygenated muriatic acid gas. I have since, however, in endeavouring to ascertain whether the electrical phænomena of galvanism were producible when the plates of the pile were oxydating, (separated from each other by a non-conductor, and in contact with an aëriform fluid only) had an opportunity of observing the very great power of this substance in producing the galvanic decomposition of water.

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* [From Nicholson's Journal, vol. iv.]

Ten pairs of plates of silver and zinc were connected by cement, so as to prevent the alternate contact of the metal. The spaces filled by cloths in the common pile were suffered to remain open, so as to admit of a free circulation of air. A tube, with water, and silver wires was adapted to the extreme plates.

This pile was introduced, without being moistened, into a vessel, provided with a stopper, filled with oxygenated marine acid gas; but no perceptible galvanic action took place. After two hours, no gas had formed in the tube, nor had any oxydation of the zinc wire been produced.* The same pile was now moistened by immersion in water. Before and after it had been wiped, it showed no signs of action in the atmosphere. It was introduced into a vessel of oxygenated marine acid gas, opened as before in the atmosphere. In a moment, the zinc wire in the tube began to oxydate with the greatest rapidity, whilst gas was given plentifully from the silver wire. The process continued to go on till the green colour had disappeared in the cylinder.

This experiment not only arranges with the facts of Fabroni and Colonel Haldane, and those I have before stated, but likewise seems to prove that the chief use of the large surface of water required in the pile of Volta is to oxydate a larger quantity of zinc: for in this instance very minute quantities of water connected the plates, and consequently very minute quantities were sufficient to enable the electrical currents to form the circuit.

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* The metals of the pile had been acted upon in this experiment, and were warm at the conclusion of it.

I am at present engaged in endeavouring to ascertain by experiments whether any differences exist in gases evolved from water by the galvanic current, when different oxydating substances form the medium of communication between the plates. When these experiments are completed, or at some future time, I shall probably offer some observations on the peculiar affinities which enable iron, zinc, &c. to decompose water only when it holds in solution atmospheric air, acids, or other bodies containing oxygen. On the principles before laid down, nothing is more easy than to explain the use of muriate of soda, muriate of ammoniac, &c. in increasing the powers of the common pile.

As the quantity of power in a pile is probably in proportion to the quantity of oxydation of the zinc, and the number of the series of plates, the pile of Mr. Cruickshank, or that I have described, will, probably, be most useful for processes, in which much galvanic power is required. In these processes, muriatic acid, or very dilute nitrous acid, may be used as the oxydating substance: for they will enable the plates to act till all the oxydable metal is destroyed, without the common trouble of cleaning and rebuilding the pile.

AN ACCOUNT OF SOME ADDITIONAL EXPERIMENTS AND OBSERVATIONS ON THE GALVANIC PHÆNOMENA.*

I. ADDITIONAL EXPERIMENTS ON THE CAUSES OF THE GALVANIC PHÆNOMENA.

1. Sulphuric acid, when highly concentrated, is possessed of but little power of action upon zinc, though when diluted it dissolves it with the greatest rapidity. Assuming then the truth of the principles advanced in my last paper, namely, that the powers of the pile of Volta are primarily excited by the oxydation of the zinc, it follows, that diluted sulphuric acid, when made the medium of connexion between the pairs of plates, ought to produce much greater effects than concentrated sulphuric acid.

This I have found is actually the case. When the cells of a series of twenty pairs of silver and zinc, constructed with waxen cement, in the mode described in 8 of my last paper, were filled with sulphuric acid, nearly of specific gravity 1·9, no galvanic action, except the production of a slight caustic taste, was perceptible by the usual methods of trial; though when dilute sulphuric acid was used, the ends of the series gave shocks to the moistened fingers, and wires connected with them effected the usual changes in water.

That concentrated sulphuric acid is not of that order of more perfect galvanic conductors which, when interposed between the plates, destroy their electrical effects, is evident, from the following experiment: the cells of ten pairs of plates of copper and zinc, constructed with waxen cement, were filled with concentrated sulphuric acid, but not the slightest galvanic power was produced. A small drop of water was then poured upon the acid in each of the cells. The action of the series was immediately shown by its producing the usual appearances on wires in water.

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* [From Nicholson's Journal, vol. iv. December, 1800.]

2. The galvanic conducting powers of liquid sulphurets are at least equal to those of water. I found that when the fingers were plunged into glasses, containing solution of sulphuret of strontian connected with the ends of a pile, the shock was full as sensible as if the communication had been made through water. When the galvanic current was made to act on solution of sulphuret of strontian by means of silver wires, the zinc wire became blackened, and gas was given out round the silver wire. But solutions of sulphurets are incapable of giving oxygen to zinc; they consequently ought to produce no galvanic effects when made the media of connexion of the double plates in the pile of Volta. Twenty-five pairs of silver and zinc, erected with cloths moistened in solution of sulphuret of strontian, produced no sensible galvanic action, though the moment the sides of the pile were moistened with a little nitrous acid, the ends gave shocks as powerful as those of a similar common pile.

3. No phænomenon is more constant than the cessation of the action of the common galvanic pile in a vacuum* when the gage is below one-fourth. Supposing the expulsion of atmospheric air from the water preventing it from oxydating the zinc, the sole cause of this cessation, it follows, that a pile ought to act in

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* See Colonel Haldane, Phil. Jour. No. 43, vol. iv.; and my last paper.

vacuo when nitrous acid, or diluted sulphuric acid is the medium of connexion between the plates. Into each of the cells of a series of twelve pairs of silver and zinc plates, which had just been moistened with a little water, a large drop of nitric acid was introduced: when the wires connected with the ends immediately began to produce the usual appearances in water. The series was introduced under the receiver of an air pump, and the silver wire from its zinc end connected with a vessel of water that had been long boiled. The wire from its silver end was so fastened by resinous cement, to a sliding brass wire passing through the top of the receiver, that it could be plunged at pleasure into the water when the vacuum was made. The receiver was exhausted till the gage stood at $\frac{6}{10}$ of an inch, when the communication was affected. The zinc wire immediately began to oxydate, and gas was given out round the silver wire. The process went on for many minutes, and when it had ceased, was not sensibly revived by the admission of the atmosphere. In another experiment, the same phænomena were observed. Gas appeared to be given out more rapidly from the silver wire than in the atmosphere; but this was from the diminution of pressure. The oxydation was certainly less, which may be easily accounted for, when we consider, that no nitrous acid could be recomposed in vacuo as in the atmosphere from the nitrous gas disengaged between the plates, and that, in consequence of the diminished pressure, some of the acid must probably have assumed the aëriform state.

A drop of sulphuric acid, poured into each of the moistened cells of twelve pairs of plates, enabled the wires from the ends to effect the usual changes in pure water for rather more than half an hour in vacuo, the gage being at $\frac{6}{10}$. The oxydation went on nearly as vividly as in the atmosphere, and what is rather remarkable, some gas was given out from the oxydating wire, though very little was produced from the silver wire.

4. The results of the last experiment are interesting not only from their coincidence with other facts, but likewise because they afford proofs that the presence of oxygen in that loosely combined or peculiar state, in which, when absorbed by combustible bodies, it produces inflammation, and in which, in my infant chemical speculations, I supposed it to be combined with the matter of light, is not essential to the galvanic effects. Whether water is absolutely essential, we shall find some difficulty in determining, as it exists in larger or smaller quantities in all the non-metallic fluid galvanic conductors that have yet been experimented upon. The following fact is in favour of its essentiality. The compound of concentrated sulphuric and oxygenated muriatic acid,* (which may be formed by introducing oxygenated muriate of potash into sulphuric acid, or by passing oxygenated muriatic acid gas through it,) slowly oxydates both zinc and silver, the oxygenated marine acid being decomposed. I expected that it would produce strong galvanic effects, when made the communicating medium of the cells of a pile; but in this I was disappointed; a series of twenty pairs connected by it produced hardly any sensible action.

5. If any person wishes to repeat the experiments in vacuo just detailed, great caution must be observed with regard to the quantities of acid introduced into the cells. Two or three drops in each will be suf-

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* I accidentally discovered this combination in July, 1799. Some of its properties are very peculiar. More interesting inquiries have hitherto prevented me from minutely examining them.

ficient, particularly if it has been previously a little moistened. When large portions are employed, the effervescence highly increased by the removal of the atmospheric pressure will be often sufficient to moisten the edges of the cells, and to make a communication between them. In consequence of the use of too much acid, I have made many unsuccessful experiments.

The water used in vacuo for connecting the wires should be always previously deprived of loose air by long ebullition, or otherwise the disengagements of that substance from it will much disturb the results.

II. OBSERVATIONS GAINED FROM MINUTE INSPECTION OF GALVANIC PROCESSES.

1. Whenever the galvanic circuit, passing through the pile with wires, is broken by means of water, oxygen is uniformly produced at the zinc metallic point, and hydrogen at the silver metallic point. This is shown from many experiments in Mr. Nicholson's Philosophical Journal. Considering analogies, an interesting question occurs. Do not the same phænomena take place in every part of the series? *i. e.* is not oxygen fixed in every plate of zinc, and hydrogen produced on every plate of silver, at the points of their contact with the water of the cloths? With the hope of gaining a solution of this question, I constructed a series of twenty glasses with spring water, containing plates of silver and zinc, connected by brass wire, in the mode pointed out by Volta. This series gave feeble shocks, and a silver wire connected with it produced the usual appearances in water. Oxygen was fixed upon that part of the wire in the glass containing the last silver plate, and hydrogen was liberated from that part of it in the glass containing the last zinc plate.

The series was made analogous in all its parts, the end glasses being connected by a pair of plates, so that every glass contained a silver plate and a zinc plate. On minutely inspecting the glasses immediately after, no particular phænomena could be perceived. But after occasional attention to the process for many hours, I observed the zinc plates beginning to oxydate in many of their points, though no gas was produced upon them. No gas had formed upon the silver plates, but the surface of the water in contact with them became covered with an opaque white pellicle.

2. The silver plates used in this experiment were not perfectly polished. This might have influenced the results, and some gas might have escaped my observation. That the operation might go on in closed vessels, I cut off the bottoms of some bottles with a file, so that they could be easily joined again by cement. Into one of these bottles I introduced a plate of polished zinc,* and into another a plate of polished silver. The plates were connected by a wire attached to their upper angles, which protruded into the atmosphere through orifices made at the places of junction of the bottoms of the phials with their sides; these places of junction being rendered perfectly water-tight by resinous cement. Four apparatuses of this kind were constructed. They were filled with pump-water, inverted in the galvanic order in glasses containing that fluid, and made part of a connected series of twenty glasses.

After more than twelve hours, the zinc plates had become tarnished, but had given out no gas. In two of the bottles with the silver plates, globules of gas, too small to be analyzed, had collected. These plates examined in the atmosphere, as well as all the other silver plates, were covered in some points with a film of white substance, which was soluble with slight effervescence, and without producing cloudiness in muriatic acid.

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* Of 1·2 inches square, the size used in all the former experiments.

3. Unable to account for the non-appearance of hydrogen during the oxydation of the zinc, I could not but conclude that it was condensed or absorbed in some new compound on the surface of the silver or the zinc. Guessing that the quantity of surface might be connected with the phænomenon of its non-appearance, I substituted in three of the phials for the square silver plates oblong ones of the same length, and about ·3 inches wide. These had not been long connected with the series before gas began to form upon them; and in four hours sufficient was collected to be examined: from the coarse test of inflammation, it appeared to be hydrogen.

Thirteen pairs of a connected series of twenty-five glasses were now composed of square zinc plates, and oblong silver plates of different sizes; some of them being about ·3, and others not more than ·1 inch wide. Gas was almost immediately given out from the greater number of the oblong plates, and in largest quantity from the smallest; from the slips of ·1 wide, indeed, a constant stream of globules ascended through the water.

Small oval, circular, and square plates, of nearly equal surfaces, with the slips connected in the series in the places of some of them, produced precisely the same effects. In short, whenever the surfaces of the silver plates did not exceed one-fourth of the quantity of the surfaces of the zinc plates, whatever were their forms, gas was always produced upon them; and both large and small surfaces in common water in a great length of time became covered at some of their points of contact with that fluid with a whitish film.

When small oblong zinc plates were introduced into any parts of the series instead of the larger plates, they appeared to oxydate rapidly, without giving off any gas.

4. The substitution of oblong silver slips for many of the plates did not apparently much diminish the power of the series; I therefore constructed a series of twenty-seven glasses, wholly composed of zinc plates attached to their silver wires. This combination with pump-water gave feeble shocks, which were less vivid than those of the common series of eighteen. When, however, it was made analogous in all its parts, all the wires not deeply inserted in the water gave out gas, and the zinc plates slowly oxydated. In another experiment, in which a series of thirty glasses, containing wires and zinc plates, were used, most of the wires not only gave out gas, but after some time became covered at their points of contact with the surface of the water with a white film; a few of them, not deeply inserted, produced a slight white precipitation.

5. These facts seemed to show that the quantity of hydrogen produced in a series, was, in some measure, and to a certain point, in the inverse ratio of the quantity of surface of the silver plates. Speculating upon them, and comparing them with the experiments of Mr. Cruickshank, and those which I noticed in my last paper on the signs of ammoniac perceived during the action of a pile in common air, I could not but conjecture that whilst oxygen was condensed on all the zinc excitors in the series, hydrogen was produced on all the silver ones; and in small surfaces chiefly liberated, whilst on larger ones it was almost wholly condensed by the nitrogen of atmospheric air dissolved in the water, and

this conjecture was rendered more probable, when I considered the white matter chiefly formed round the silver at the surface of the water, and its solubility, without cloudiness in acids, as it might easily have been produced by the decomposition of Magnesian salts existing in the pump-water.

To determine whether ammoniac was produced, I made many experiments on the different series, consisting of from seventeen to thirty glasses. In some of these glasses wires were used, and in some of them plates. Sometimes distilled water was employed, and sometimes pump-water, both of which were occasionally tinged with red cabbage juice.

Without being minute in the detail of these experiments, I shall give their general results. In the vessels containing the red-cabbage-juice, that fluid, after many hours, became tinged with green where it was in contact with the silver, though at its point of contact with the zinc no change of colour could be observed in it. In the pump-water a white film always formed on the surface of the water near its point of contact with the silver: whilst in distilled water such an appearance was hardly perceptible. The anomaly of its being now and then perceptible I am inclined to refer to accidental impurities in the vessels. The silver slips in pump-water almost always became incrusted with a white matter, which was never notable in distilled water, and which was soluble, without cloudiness, in nitrous acid.

In one experiment, when a silver slip, forming part of a powerful series, was introduced into a small vessel, containing solution of muriate of magnesia* (connected with the next zinc glass by means of muscular fibre, to prevent the interference of the oxydating metal with the results), in the course of a night much gas was given out from it, and it became incrusted with a white matter, which dissolved with slight effervescence in marine acid. A precipitation had taken place in the fluid.

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* Muriate of magnesia was used in preference to nitrate or sulphate, because there was a possibility of the decomposition of the acids in

These results afford strong probabilities in favour of the production of ammoniac on all the silver excitors of the series formed with common water: and compared with the facts before-mentioned, they amount almost to demonstrations. Whether the nitrogen of atmospheric air dissolved in water is the agent which forms with the hydrogen ammoniac, future experiments made in vacuo must determine.*

6. The power of the series with silver wires, was much less than that of the series with plates. Supposing the formation of ammoniac, it was probable, that the larger quantity produced upon the plates, might be in some measure the cause of their greater powers; and if so, it was likely that the condensation of nascent hydrogen upon the wires would be connected with increase of power. From the following facts it appears that this is the case. A series of thirteen plates of zinc,

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these salts by the nascent hydrogen, which alone would occasion a precipitation of the earth.

* Mr. Cruickshank, who first noticed the probable formation of ammoniac on the silver wire of the pile, has offered some ingenious arguments to prove that nitrous acid is formed at the zinc wire. Analogy would induce us to conjecture, that if it was formed on one of the oxydating surfaces, it ought to be formed on all. That no change of colour takes place in cabbage-juice, in contact with the oxydating zinc plates, may be owing to the great extension of their surfaces. It is worth observing, that the silver oxydates as rapidly in water in vacuo as in the atmosphere, when the pile is in the atmosphere; or when nitrous or sulphuric acid is used on the cells in vacuo.

with their silver wires constructed in glasses, containing weak solutions of red sulphate of iron, mingled with a little solution of common sulphate of iron and nitrous gas, acted full as powerfully as the common series of twenty plates. The wires gave out no hydrogen, but occasioned a brown precipitation in the fluid, and the zinc plates soon became covered with green oxyde of iron. The phænomenon was the same with the other metallic solutions, capable at the same time of absorbing hydrogen and oxydating zinc.

7. The strongest analogies would induce us to believe, that all the galvanic series composed of easily oxydable metals and difficultly oxydable metals must follow the same laws in producing changes in their connecting fluid as zinc and silver. But as from the interesting facts of Colonel Haldane, it appeared that iron and zinc as a combination were possessed of very considerable powers, and as iron is but little inferior to zinc in its affinity for oxygen, it became a curious question what would be the habitudes of those metals in effecting changes in the water constituting them a series. Sixteen zinc plates, and sixteen pieces of thin polished iron wire, were connected in galvanic order. One-half of the series of glasses being filled with solution of red sulphate of iron, and the other half with pump-water, the end glasses gave faint shocks when the tongue was introduced into one, and the fingers into the other. When they were connected so as to make the series analogous in all its parts, all the iron wires in the common water gave out gas without oxydating, and these in the solution exhibited the same appearances as the silver wires in II. 6.

8. A series of glasses composed of zinc plates and silver wires in galvanic order with pump-water, was

suffered to remain for some hours without being connected at the extremity so as to complete the circuit. At the end of this time some globules of gas appeared on some of the zinc plates, which were a little tarnished; no gas was produced on the silver wires, and they had undergone no apparent change.

Having set up a powerful series of 27 glasses, (some with red sulphate of iron, and some with water), in which zinc and silver wire were the excitors, I found that whenever I supplied the place of a pair of plates, either by a single metallic wire, or a chain composed of different metals, whatever were their habitudes of oxydation, hydrogen was always produced at the place of the silver, and oxygen always fixed or extricated at the place of the zinc. When many silver wires were introduced into the series in new glasses, so as to preserve the original number of exciting plates, the powers of it seemed to be very little diminished, and gas was given out, and oxygen fixed in every new glass. When the points of contact of some of the plates and wires above the water were covered with cement, the phænomena were the same as if they had been exposed to the atmosphere. When one pair of a series was in vacuo, the gage being at $\frac{6}{10}$, the powers of the whole were not sensibly diminished.

9. On these facts I shall not presume to speculate. There is every reason to believe that a number of new experiments must be made, before we shall be able to discover the laws in consequence of which one quantity of chemical action generates in the galvanic series of Volta, an influence capable of increasing all analogous actions, and of generating new similar actions. Many new observations must be collected, probably before we shall be able to ascertain whether water is decomposed

in galvanic processes. Supposing its decomposition, we must assume, that at least one of its elements is capable of rapidly passing in an invisible form through metallic substances, or through water and many connected organic bodies; and such an assumption is incommensurable with all known facts. But a short period has elapsed since philosophers beheld with wonder, solid and fluid substances assuming new modes of existence in different gases. Do not the new phænomena of galvanism authorise us to hope, that at no very distant time they will behold even those gases undergoing novel changes, and existing in new and now unknown forms?

III. REMARKS ON THE POWERS OF DIFFERENT GALVANIC COMBINATIONS.

1. I have found by many experiments, that when muriatic acid is introduced (in quantities sufficient to produce visible changes) into water contained in the glasses of an effective galvanic series composed of zinc plates, and silver wires, the zinc plates are acted upon, and gas is given out from every part of their surfaces; whilst the quantities of gas produced on the silver wires are increased only in the apparent ratio of the increased power of the series to give the shock. When muriatic acid is introduced into a certain number only of the glasses of a series, similar changes are produced in these glasses; but there is no apparent alteration in the nature of the phænomena taking place in the other glasses; these phenomena are only rendered more vivid. Effects analogous in *appearance* take place when the sulphuric acid, and even when the nitric acid is employed. So that it appears that the power of a series to fix oxygen upon its zinc plates, and to evolve hydrogen from its silver plates, is limited, and cannot be increased

by oxydating bodies beyond a certain extent. We must consequently conclude, that only a certain quantity of galvanic influence can be made to circulate through a series in a given time, and that the increase of oxydation beyond a certain time is connected with no new increase of power.

2. The substances which are capable of rapidly oxydating the imperfect metals and of condensing nascent hydrogen at the same time, are those which produce the most powerful effects, when made the medium of connection between the metals in the galvanic series. The nitric and oxygenated marine acids appear to be the most powerful of the known fluid excitors of the pile. The solutions of metallic salts, composed of acids and oxyds at their maximum of oxydation, stand next in order; then follow the muriatic and sulphuric acids, and the neutral salts containing these acids, or nitric acid.

I have lately endeavoured to make some comparisons between the powers of piles constructed with nitric acid, and those of common piles; but without much success. The rapid action of the acid, the evolution of gases connecting the plates by moisture, and the production of heat, all tend to disturb the results. The smallest series of plates from which I was able to obtain shocks by nitric acid, was composed of three pairs. Six pairs, with moderately strong nitric acid, gave a shock more acute than that produced by a common pile of twenty-seven pairs, but apparently much more limited in extent: it was felt no further than the upper joints of the fingers. With twelve pairs, or still more numerous combinations, the shock was always more acute and painful, than from a common pile composed of four or five times the number of plates; but apparently more local, and felt over a smaller surface. As fusion of the cement always took place when the trough was used in these experiments, cloths wetted with the acid were generally employed; but in no case was it possible to prevent the edges of the plates from being moistened, so that a certain degree of communication between the ends always existed, and from this communication the effects must have been much diminished. A pile with nitric acid had its power very little lessened by momentary immersion in water. Hence the increase of effect cannot much depend on the increased temperature of the plates.

3. Copper and zinc act very powerfully with nitric acid. Iron and zinc seem to act nearly as intensely with muriatic acid as with nitric acid.

The galvanic combinations that I have been lately most in the habit of using, are series of glasses constructed with zinc plates, silver or iron wire, and solutions of red sulphate or muriate of iron. These combinations act for a long time intensely; six or eight glasses being capable of slowly decomposing water; and if their action is at any time diminished from the deposition of oxyd of iron on the zinc plates, it may be easily restored by the addition of a little acid to the solution.

4. I noticed in a former paper the conducting powers of charcoal, when made part of the galvanic circle.* I lately set up a series of eight glasses, with small pieces of well burnt charcoal, zinc, and solution of red sulphate of iron; the charcoal and zinc being connected by silver wire. This series gave sensible shocks, and rapidly evolved gases from water; whilst an equal series with

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* Dr. Wells, in an excellent paper on galvanism, in the Philosophical Transactions has mentioned the great powers of an arc composed of charcoal and zinc in exciting the limbs of frogs.

silver and zinc produced much weaker effects. Hence it would appear that charcoal and zinc are equal, if not superior, to any metallic combinations.

LETTER TO MR. NICHOLSON, CONTAINING NOTICES CONCERNING GALVANISM.*

SIR,

IN pursuing my inquiries concerning the production of galvanic influence during metallic oxydation, I have found that many of the difficultly oxydable metals may be made to act as Voltaic combinations, by being connected in pairs in the common order with fluids capable of oxydating one of the alternate metals.

Ten silver plates attached to thin gold wires, and arranged in glasses containing diluted nitric acid, produced when their agency was applied in the usual mode, a strong caustic sensation on the tongue, and effected, though feebly, the usual changes in water.

Twenty pieces of copper in contact with silver wires, when connected with weak solutions of nitrate of mercury act powerfully, and that for a great length of time, *i.e.* till almost all the mercury was precipitated on the copper. The influence produced sensible shocks. When it was passed through water by means of gold wires, oxygen was given out at the place of the copper, and hydrogen at the place of the silver. Whereas in the combination with silver and gold, the oxygen was produced at the place of the silver, and the hydrogen at that of the gold.

The agency of galvanism upon inorganic bodies appears to be similar under all the different modes of

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[* From Nicholson's Journal, vol. iv. February, 1801.]

excitement. I have found that the gases evolved from water by the action of series in which the oxydating fluid media are acids or metallic solutions, do not differ in kind or properties from those produced by that of combinations in which the fluid media are constituted by common water.

I have lately made many experiments on the single oxydating circles of Ash, and on the influence of these circles on galvanic animal irritation. These experiments will at some time be made public; they go far towards proving not only that the circles of Ash are governed by the same laws as the pile of Volta; but likewise that there exists in living matter galvanic action independent of all influence generated by metallic oxydation. I have produced the phænomena of taste and muscular irritation by means of metals, in cases when they were apparently incapable of undergoing chemical change.

I am, Sir, &c.
(Signed) HUMPHRY DAVY.

Dowry Square, Hotwells, January 23, 1801.

AN ACCOUNT OF SOME GALVANIC COMBINATIONS, FORMED BY THE ARRANGEMENT OF SINGLE METALLIC PLATES AND FLUIDS, ANALOGOUS TO THE NEW GALVANIC APPARATUS OF MR. VOLTA.*

1. ALL the galvanic combinations analogous to the new apparatus of Mr. Volta, which have been heretofore described by experimentalists, consist (as far as my knowledge extends) of series containing at least two metallic

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[* From Phil. Trans. 1801.]

substances, or one metal and charcoal, and a stratum of fluid. And it has been generally supposed, that their agencies are, in some measure, connected with the different powers of the metals to conduct electricity. But I have found that an accumulation of galvanic influence, exactly similar to the accumulation in the common pile, may be produced by the arrangement of single metallic plates, or arcs, with different strata of fluids.

The train of reasoning which led to the discovery of this fact, was produced by the observation of some phænomena relating to the connection of chemical changes with the evolution of galvanic power.

It appeared, in several experiments, that series of double metallic plates, incapable of acting as galvanic combinations, when arranged in the proper order, with portions of water, were readily made to produce galvanic effects, by being alternated with acids, or other fluids capable of oxydating one only of the metals of the series. Thus, double plates, composed of silver and gold, (metals which have been supposed to differ very little in their powers of conducting electricity) produced galvanic action, when placed in contact, in the common order, with cloths moistened in dilute nitric acid. And copper and silver acted powerfully with nitrate of mercury.

These facts induced me to suppose, that the alternation of two metallic bodies with fluids, was essential to the production of accumulated galvanic influence, only so far as it furnished two conducting surfaces of different degrees of oxydability; and that this production would take place, if single metallic plates could be connected together by different fluids, in such a manner that one of their surfaces only should undergo oxydation, the arrangement being regular.

On this supposition, I made a number of experiments on different arrangements of single metals and fluids; and, after many various processes, I was enabled to ascertain, that many of these arrangements could be made active, not only when oxydating, but likewise when other chemical changes were going on in some of their parts.

In describing the different galvanic combinations formed by single metallic plates and fluids, I shall divide them into three classes, following, in the arrangement, the order of time with regard to discovery.

II. The first and most feeble class is composed, whenever single metallic plates, or arcs, are arranged in such a manner that two of their surfaces, or ends opposite to each other, are in contact with different fluids, one capable, and the other incapable, of oxydating the metal. In this case, if the series are numerous, and in regular alternation, galvanic influence will be accumulated, analogous in all its effects, to the influence of the common pile.

Tin, zinc, and some other easily oxydable metals, act most powerfully in this class of combinations.

If pieces of polished tin, about an inch square, and $\frac{1}{20}$ of an inch thick, be connected with woollen cloths of the same size, (moistened, some in water, and some in diluted nitrous acid,) in the following order, tin, acid, water, and so on, till twenty series are put together, a feeble galvanic battery will be formed, capable of acting weakly on the organs of sense, and of slowly producing the common appearances on water; the wire from the oxydating surface of the plates evolving hydrogen, and the wire from the non-oxydating surface (when of silver) depositing oxyde.

In all cases, when the batteries of the first class are erected perpendicularly, the cloth moistened in acid must be placed under the cloth moistened in water; and, in this arrangement, as the acid is specifically heavier than water, little or no mixture of the fluids will take place.

When zinc is employed, on account of its rapid oxydation in water containing atmospheric air, three cloths should be used; the first moistened in weak solution of sulphuret of potash, (which is possessed of no power of action upon zinc, and which prevents it from acting upon the water;) the second moistened in a solution of sulphate of potash, of greater specific gravity than the solution of sulphuret; and the third wetted in an oxydating fluid specifically heavier than either of the solutions. In this case, if the order be as follows, zinc, oxydating solution, solution of sulphate of potash, solution of sulphuret of potash, very little mixture of the fluids, or chemical action between them, will take place: and an alternation of twelve series of this kind, forms a battery capable of producing sensible effects.

III. The second class of galvanic combinations with single plates is formed, when plates, or arcs, composed of a metallic substance capable of acting upon sulphuretted hydrogen or upon sulphurets dissolved in water, are formed into a series, with portions of a solution of sulphuret of potash, and water, in such a manner that one side of every plate, or arc, is in contact with water, whilst the opposite side is acted on by the solution of sulphuret. Under these circumstances, when the alternation is regular, and the number of series sufficiently great, galvanic power is evolved; and water, placed in the circuit with silver wires, is acted on; oxyde being deposited on the wire connected with the side of the plate undergoing chemical alteration, whilst hydrogen is evolved from the side in contact with water.

Silver, copper, and lead, are each capable of forming this combination. Plates made from either of these metals, may be arranged with cloths (moistened, some in water, and others in solution of sulphuret of potash) in the following order, metal, cloth moistened in sulphuret of potash, cloth moistened in water, and so on.

Eight series will produce sensible effects; and the wire from the top of the pile produces oxyde.

Copper is more active in this class of batteries than silver; and silver more active than lead.

IV. The third and most powerful class of galvanic batteries, constructed with fluids and single metals, is formed, when metallic substances, oxydable in acids, and capable of acting on solutions of sulphurets, are connected, as plates, with oxydating fluids and solutions of sulphuret of potash, in such a manner that the opposite sides of every plate may be undergoing different chemical changes; the mode of alternation being regular.

The same metals that act in the second class, may be used in the third class; and the order of their powers is similar. The pile may be erected in the same manner as the pile with zinc in the first class; the cloths moistened in acid being separated from those moistened in solution of sulphuret, by a third cloth, soaked in solution of sulphate of potash.

Three plates of copper, or silver, arranged in this manner, in the just order, produce sensible effects; and twelve or thirteen series are capable of giving weak shocks and of rapidly producing gas and oxyde in water; the wire connected with the oxydating end of the apparatus evolving hydrogen; and the wire attached to the end acting on the sulphuret, depositing oxyde when composed of silver, and generating oxygen when of gold.

V. In all the single metallic piles constructed with cloths, the action is very transient; the decomposition of the acids, and of the sulphurets, is generally completed in a few minutes; and, in consequence, the galvanic influence ceases to be evolved. The arrangement of all the different series may, however, (by means of an apparatus constructed after the ideas of Count Rumford) be made in such a manner as to give considerable permanency to their effects. This apparatus is a box, covered with a cement incapable of conducting electricity, and composed of three pieces of mahogany, each containing grooves capable of receiving the edges of the different plates proper for composing the series. One-half of these plates must be composed of horn, or glass, and the other half of metallic substances; and the conductors of electricity, and the non-conductors, must be alternately cemented into the grooves, so as to form water-tight cells.

When the apparatus is used, these cells are filled in the galvanic order, with different solutions, according to the class of the combination; and connected in pairs with each other, by slips of moistened cloth, carried over the non-conducting plates.

A combination of fifty copper-plates, arranged in this manner with weak solutions of nitrous acid, or nitrate of ammoniac, and sulphuret of potash, gives pretty strong shocks, rapidly evolves gas from water, and affects the condensing electrometer.

It does not lose its power of action for many hours; and when this power is lost, it may be restored by the addition of small quantities of concentrated solution, of the proper chemical agents to the fluids in the different cells.

From the experiments made on copper and silver, it would appear that the single metallic batteries act equally well, when the metals made use of are slightly alloyed, and when they are in a state of purity.

OUTLINES OF A VIEW OF GALVANISM, CHIEFLY EXTRACTED FROM A COURSE OF LECTURES ON THE GALVANIC PHÆNOMENA, READ AT THE THEATRE OF THE ROYAL INSTITUTION.*

I. Historical Introduction.

1. The science relating to the peculiar action of different conductors of electricity on each other, has lately excited a considerable degree of attention in the philosophical world.

Owing its origin to the phænomenon discovered by Galvani,† the production of muscular action by the application of metals to the nerves and muscles of animals, it has derived its name from that philosopher.‡

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* [From Journals of the Royal Institution, vol. i. 1802, edited by Dr. Thomas Young and the author. This historical sketch of Galvanism is chiefly interesting as strongly showing its rapid progress.]

† The first fact relating to the action of metals on the animal organs was observed by Sulzer, who has described the sensation of taste produced by the contact of lead and silver with the tongue, in his *Theorie des plaisirs*, published in 1767.

‡ [This discovery was made at Bologna by Galvani in 1789, and a detailed account of it given in a work expressly on the subject, entitled Aloysii Galvani *de Viribus Electricitatis in Motu musculari Commentarius*. Bononiæ, 1791, in 4to. Volta, in his letter to Mr. Cavallo, published in the Philosophical Transactions for 1793, making mention of it, says, "Il contient une des plus belles et des plus surprenantes découvertes, et le germe de plusieurs autres."]

Galvanism was at first limited in its application to organized bodies; but in consequence of the labours and inventive genius of experimentalists, our contemporaries, it has gradually become connected with chemistry and general physics; it has afforded powerful instruments of investigation; and its operations have been traced throughout the whole of nature. In giving an account of the progress of this science in its relation to the powers of the human mind, it will be sufficient to notice such experiments only as have derived their origin from extensive theoretical views, and such discoveries as have led to accurate generalizations of phænomena already known.

Though the history of galvanism extends only through the period of the last nine years, yet we may notice in it four epochs, each of them distinguished by the development of facts variously interesting from their novelty and the extent of their application.

2. Considering the first epoch as formed by the publication of the fundamental galvanic fact, we may derive the second from the discovery of the existence of inorganic galvanism. Till the researches of Fabroni, Dr. Ash, and Creve, had been made known, the galvanic influence was generally considered as existing only in living animal organs. But the discovery of the peculiar action of metals in contact with each other upon water, demonstrated the production of it in arrangements composed wholly of dead matter, and laid the foundation for a new class of investigations, which have intimately connected the galvanic phænomena with known physical effects.

3. The third epoch in the history of this science is perhaps the most brilliant and important. It will long be celebrated on account of the discovery of the accumu-

lation of the galvanic influence. Before this discovery was made, the world, in general, beheld nothing deeply interesting in galvanism; it had no relations to the common wants of life, and the facts that composed it were so obscure as to be with difficulty comprehended, except by long attention. The galvanic battery of Volta, not only gratified the passion for novelty by the curious effects it produced, but likewise awakened the love of investigation, by distinctly exhibiting the analogy between galvanism and common electricity.

4. The fourth and last epoch in galvanism may be considered as founded upon the knowledge of the general connexion between the excitement of galvanic electricity and chemical changes; and it chiefly owes its existence to the labours of British experimentalists.* The discovery of the chemical agencies of galvanism, has led to researches which finally cannot fail to elucidate the philosophy of the imponderable or etherial fluids. The year that is past will long be distinguished in the history of science; seldom has physical investigation been pursued with greater ardour, and if new facts, by being sometimes insulated, and incapable of application to established theories, have perplexed the public mind, yet they have at the same time been useful to it, by producing a habit of rational and active scepticism which cannot fail to become at a future period the parent of truth.

II. OF THE LEAST COMPLICATED GALVANIC ARRANGEMENTS, *i. e.* SIMPLE CIRCLES.

1. The conductors of electricity, which by their action on each other are capable of producing galvanic

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* Messrs. Nicholson, Carlisle, Cruickshank, and Henry, Dr. Wollaston, and Major Haldane.

effects, may be divided into two classes.* The one class comprises what may be called perfect conductors, oxydable metallic substances and charcoal. The other includes less perfect conductors, which are either oxydated fluids, or substances containing these fluids.

The simplest galvanic arrangements require for their formation at least two bodies of the same class, and one of a different class.* With regard to the form of their aggregation, they must be so disposed that the bodies of the one class may be in contact with each other, in one or more points, at the same time that they are connected in other distinct points with the body of the other class.

2. The simple galvanic circles may be divided into two general kinds.

The first is formed by two different metallic substances, or one metallic substance and charcoal, and a peculiar fluid.

The second is composed by two different fluids and one metallic substance.

Thus, if plates of zinc and of silver be made to touch in one point, and be connected together in other points by a portion of common water, or of muriatic acid, a galvanic simple circle is formed of the first order.

Or if separate portions of nitric acid and of water moistening pieces of cloth or bibulous paper be brought in contact with each other on a small surface, at the same time that other surfaces of them are connected with different parts of a plate of tin, a circle of the second kind is composed.†

3. All arrangements, however, of two conductors of one class with one of the other are not capable of producing galvanic effects. And even the powers of acting circles are very different in degree. It appears, from

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* Volta.

† D.

all the facts, that chemical changes taking place in some of the parts of the circle, are intimately connected with its agencies. For though a momentary circulation of galvanic influence may possibly be produced by the contact of three different bodies, yet it appears most likely that the permanent excitation of it depends upon a certain exertion of their chemical affinities.

The most powerful circles of the first kind are those composed of two solids of different degrees of oxydability, and of a fluid capable of oxydating at least one of the solids.* And even in the feeblest circles, it appears that some chemical action is uniformly exerted either by oxydating fluids, or solutions of alkaline sulphurets.

Thus, silver and gold do not appear to evolve galvanic influence when in contact with pure water, which is incapable of acting chemically upon either of the metals; though when they are connected with water holding in solution nitric acid, or any other fluid decomposable by silver, they form an active galvanic arrangement.†

And zinc and silver, which act very little with pure water, form a powerful combination with water holding in solution atmospheric air, or acids.‡

The following table of some circles of the first kind, in which the different substances are arranged according to the order of their known galvanic powers, will shew how intimately chemical agencies are related to the production of galvanism.

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* Ritter. † D. ‡ Fabroni.

TABLE OF SOME GALVANIC CIRCLES,

COMPOSED OF TWO PERFECT CONDUCTORS AND ONE IMPERFECT CONDUCTOR.

More oxydable substances.	Less oxydable substances.	Oxydating fluids.
Zinc . . .	With gold, charcoal, silver, copper, tin, iron, mercury.	Solutions of nitric acid in water, of muriatic acid and sulphuric acid, &c. Water holding in solution oxygen, atmospheric air, &c.
Iron . . .	—— gold, charcoal, silver, copper, tin.	
Tin . . .	—— gold, silver, charcoal.	
Lead . .	—— gold, silver.	Solution of nitrate of silver and mercury, nitric acid, acetous acid.
Copper .	—— gold, silver.	
Silver . .	—— gold.	Nitric acid.*

The most active single circles of the second order are those in which the two imperfect conductors are capable of exerting different chemical agencies on the perfect conductor, at the same time that they are possessed of power of action on each other. But even circles in which only one of the fluid parts is decomposable by the solid, are possessed of power of action.

Thus, copper, silver, or lead, acts very powerfully when connected in the proper order with solutions of alkaline sulphurets and of nitrous acid, both of which fluids are possessed of distinct chemical agencies upon them,† and copper or silver acts, though with less intensity when water, or a fluid which they are incapable of decomposing, is substituted for one of the chemical agents.

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* Dry nitre, caustic potash, and soda, are conductors of galvanism, when rendered fluid by a high degree of heat, but the order of their conducting powers has not yet been ascertained.

† D.

The following Table contains some powerful galvanic combinations of the second order, arranged according to the intensity of their action.

TABLE OF SOME GALVANIC CIRCLES,

COMPOSED OF TWO IMPERFECT CONDUCTORS AND ONE PERFECT CONDUCTOR.

Perfect Conductors.	Copper .	Imperfect Conductors.	Solutions of alkaline sulphurets capable of acting on the first three metals, but not on the last three.	Imperfect Conductors.	Solutions of nitrous acid, oxygenated muriatic acid, &c. capable of acting on all the metals.
	Silver . .				
	Lead . .				
	Tin . . .				
	Iron . . .				
	Zinc . . .				

4. Arrangements exactly similar in their action to the common simple circles may be formed by the combination of more than three conductors. For, that simple galvanic action may be evolved, nothing more is apparently requisite than that the points of contact between the solid and fluid parts of the circle, i. e. the places where chemical affinities are liable to be exerted, be immediately preserved; at the same time that those parts are respectively homogeneal, or composed respectively of similar conductors. Thus, zinc, silver, iron, gold, and water, arranged in a circle in the order of their enumeration, produce action exactly analogous to zinc, gold, and water. And nitrous acid, water, solution of caustic potash, solution of sulphuret of potash, and silver, evolve galvanic influence in the same

manner as nitrous acid, water, solution of sulphuret of potash, and silver.

It appears, however, that the length and surface of the conducting series, connecting the exciting parts of the circle, are in some measure related to the quantity of action it is capable of exhibiting. This law, indeed, applies only analogically to perfect conductors; though, with regard to imperfect conductors, it is demonstrated experimentally; as in all cases, a diminution of power, in some unknown ratio, is produced by the increase of the length, or what is apparently equivalent, the diminution of the surface of the chain which they compose.

The limits of surface and of length of imperfect conductors in circles, connected with the maximum and minimum of their activity, have not yet been ascertained; and there is every reason to believe that they will be different in different imperfect conductors. Thus, portions of sulphuric acid, and of nitrous acid, will probably form better conducting series than similar portions of water; and a chain of water will perhaps act better than an equal chain of water mixed with alcohol.

From several experiments, it would appear that the powers of circles are particularly connected with the extension of the surfaces of contact between the perfect and imperfect conductors.

5. All galvanic influence in single circles is manifested, either by its efficiency, in affecting living animal organs, forming part of the arrangement, or by its power in modifying the chemical changes produced by the action of the perfect on the imperfect conductors.

A. When one part of a powerful single circle is made to touch the tongue at the same time that another fluid part is connected with some irritable surface of the body, an acid taste is perceived,* which becomes less distinct in proportion as the contact is longer preserved.

If the eye be made part of the galvanic circuit, a transient flash of light is produced at the moment the chain is completed,† and when the bared cutis is employed, a faint painful sensation uniformly denotes the circulation of the galvanic influence.‡

But the most distinct mode of exhibiting, by animal excitement, the existence of small quantities of galvanic power, is by connecting one part of a circle with a nerve, and another part with a muscle in a limb just separated from the body of a living animal. In this case, whenever the connexion of the arrangement is made, or broken, muscular contractions are produced.§

B. In galvanic simple circles, all primary chemical action taking place between the imperfect and perfect conductors, is apparently increased by their galvanic arrangement. Thus, zinc, which oxydates when in contact with common water alone, oxydates much more rapidly when forming a galvanic circle with it by means of gold, or other difficultly oxydable metals.‖ And tin appears to dissolve faster in diluted nitric acid, when composing a circle with it by the contact of gold, than when singly immersed in it.¶

C. But increase of primary chemical action is not the only inorganic effect of galvanism; for it changes the nature of this action in a very peculiar manner.

In the oxydating circle with common water, no perceptible quantity of hydrogen is evolved, as in common processes, but an alkaline substance appears to be formed at the point of contact of the least oxydable perfect conductor with the fluid. Thus, if zinc and silver be made to form a circle with distilled water holding in solution air, for many weeks, a considerable oxydation of the zinc is perceived, without the perceptible evolution of gas; and the water at its point of contact with the silver, becomes possessed of the power of tinging green, red-cabbage-juice, and of rendering turbid solution of muriate of magnesia.*

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* Sulzer, Volta, Robinson, and other philosophers.

† Mr. Hunter. ‡ Humboldt. § Galvani. ‖ Dr. Ash.

¶ Original Experiment D.

In the oxydating circles with acids, gas is not only evolved from the parts of the conductors undergoing chemical change, but likewise from other parts, in which no primary action apparently exists. Thus, when zinc and silver form a circle with diluted muriatic acid, gas is not only given out at the point of contact of the acid with the zinc, but likewise at the place where it is connected with the silver.† And in the circle with tin, gold, and diluted nitric acid, nitrous gas is evolved from the gold as well as from the tin.*

D. Indeed, in all the single galvanic circles, whenever an oxydating influence is exerted at one of the places of contact of the perfect and imperfect conductors a de-oxydating action appears to be produced at the other place. Thus, when iron, which oxidates rapidly when forming a circle with silver and common water, is arranged with zinc and common water, it remains perfectly unaltered whilst the zinc is rapidly acted upon.

6. The phænomena exhibited by the simple galvanic circles cannot well be theorised upon, except in the laws of their connection with the more complicated and more striking galvanic facts. And it is from the discovery made by Volta of the accumulation of galvanism only, that the instruments of investigation are derived, by means of which the nature of this influence is

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* Original Experiment D.

† Dr. Wollaston.

known, and its most important agencies and relations ascertained.

III. OF COMPOUND GALVANIC CIRCLES OR GALVANIC BATTERIES.

1. The instruments for accumulating galvanic power, or the compound galvanic circles are composed of the same elements, as the simple circles; but those elements are disposed in a different power of aggregation.

To compose a galvanic battery, series of the conductors capable of forming simple circles are required. And they must be arranged in such a manner, that the conductors of the same class in every series, may be in contact with each other, in one or more points, at the same time that they are respectively connected with different conductors of the other class, and one of them belonging to the same series, a regular alternation being observed.

Thus the order of a compound galvanic circle is, conductor of the one class, conductor of the other class, conductor of the one class, conductor of the other class; and so on in uniform arrangement.

2. The compound galvanic circles, like the simple circles, may be divided into two general orders. The first order is composed of series containing at least two perfect conductors and one imperfect conductor. The second is formed by arrangements, consisting of not less than two imperfect conductors, and one perfect conductor.*

Thus if plates of zinc, and of silver, and pieces of cloth of the size of the plates, moistened in water or diluted muriatic acid, be arranged in the order of zinc, silver cloth; zinc, silver cloth, and so on till twenty series are perfectly connected, a galvanic battery is formed of the first class.*

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* D.

And if plates of copper and pieces of cloth, moistened, some in water, and some in solution of sulphuret of potash, be connected in a circle, in the order of copper, cloth moistened in water, cloth moistened in solution of sulphuret of potash, and so on, a compound circle will be formed of the second class.†

The most elegant mode however of arranging the metals of compound circles with fluids, is by means of vessels, composed of electrical non-conductors, such as glasses or boxes formed of baked wood.

Thus plates of copper and of zinc, paired, and soldered together at their edges, may be cemented into a trough composed of baked wood in regular alternation, and in such a manner as to leave a number of water-tight cells, corresponding to the number of series. And this arrangement will become active, when the cells are filled with water or saline solutions, and when the extreme metals are properly connected.‡

Or instead of the double plates, single plates of copper, and of horn, or glass, may be used in uniform alternation; when the cells must be filled with different fluid chemical agents in the regular order so as to be connected together by pieces of moistened cloth passing over the non-conducting plates.§

3. The substances most active in the single circles, are likewise most active in the compound circles. And in all cases, the relative quantities of galvanic power exhibited by equal numbers of different series, are, in some measure, proportional to the intensity of the peculiar primary chemical agencies, exerted by

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* Volta. † D. ‡ Mr. Cruickshank. § Count Rumford.

the different conductors composing them on each other.[*]

Thus in the battery with zinc and silver, there is no action produced when the connecting fluid is pure water, or water holding in solution hydrogen gas, which is incapable of acting on the metals.[†] The action is greater with water saturated with oxygen[‡] than with water saturated with atmospheric air, and it is most intense when solution of red sulphate of iron, or of nitric acid is employed.

The tables of the single circles will indicate with the necessary change of arrangement, the relative powers of the series forming compound circles.

4. Provided those places of contact in the compound circle in which the peculiar chemical changes are produced, remain permanent, the parts of the series which do not immediately act chemically on each other, may be connected together in the same manner as in single circles, by means of conductors of their own class, without any alteration of the nature of the agencies.

Thus, in the circle with copper, iron, and water, the copper and iron may be connected by means of a wire of brass.[§] And even the continuity of the portions of water may be broken by moist muscular fibre, and other imperfect conductors, without any other change in the effect than a diminution of its intensity.[‖]

5. The galvanic influence when highly accumulated, produces very extraordinary chemical and physical effects, and in many of its appearances, assumes the precise form of common electricity.

A. When in a powerful battery (one for instance containing two hundred series) the communication, after being broken, is again rendered complete, by the contact of two perfect conductors, a flash, or spark of light is perceived, analogous to that produced by electricity.* This spark, or flash, when the battery is most powerful, is capable of passing through a considerable stratum of air,† and of inflaming mixtures of oxygen and hydrogen.‡ When the metallic substances by which it is transmitted, are of very small volume, it is possessed of the power of igniting them; and of making them enter into combustion when in contact with oxygen.§

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[*] D.

[†] D.

[‡] Major Haldane.

[§] Volta.

[‖] Pfaff, Ritter, and D.

B. The galvanic influence, when highly concentrated, affects the electrometer, and is capable of communicating weak charges to the condenser and Leyden phial.‖ In all compound circles of the first class, the most oxydable part of the metallic plates evolves the influence, appearing as positive electricity, whilst the least oxydable part seems negatively electrified. In the second class of circles, it is, however, probable that this order is reversed.

C. Galvanism, moderately accumulated, affects the animal organs in nearly the same manner as common electricity. When the human body is made part of the circle, a shock is perceived at the moment of connection; and a subsequent numbness, and tingling sensation, denote the permanent circulation of the influence.

The fresh limbs of frogs undergo violent contractions, and soon lose their excitability, when placed in the circuit of a powerful battery.

D. The chemical actions taking place in the compound galvanic circle, present curious and most unexampled appearances; all the primary changes taking place in the different conductors being increased, and modified to a great extent.

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* Volta. † Mr. Cruickshank. ‡ Mr. R. Boulton.

§ Professors Tromsdorf, Bockman, Fourcroy, and Vauquelin.

‖ Mr. Nicholson and Mr. Cruickshank.

In all batteries of the first order, when the connection is completed, changes take place which denote the evolution of influences capable of producing from *common* water, oxygen and hydrogen, acid and alkali, in different parts of every series.*

Thus in the battery with series of zinc plates, silver wires, and common water, oxyde of zinc is formed on all the plates of zinc, whilst hydrogen is produced from the silver wires, and if the water in them be tinged with red-cabbage-juice it becomes green.†

And in the battery with silver, gold, and weak nitric acid, the silver is dissolved, while the acid becomes green, and slowly evolves gas at its points of contact with the gold.

The chemical agencies exerted in the compound batteries of the first class can be best observed by the substitution of single metallic wires for some of the double plates; for in this case, the changes taking place in the series with wires will be exactly analogous to those produced in the series with plates; silver and all the more oxydable metals, oxydating in water in the usual place; and gold, and platina evolving oxygen gas.

Thus, when into two small glass tubes connected by moist animal substance, and filled with distilled water, two gold wires are introduced from a large battery, in the proper order, oxygen is produced in one quantity of water, and hydrogen in the other, nearly in the proportions in which they are required to form water by combustion.‡ And if the process be continued for some time, the apparatus, being exposed to the atmosphere, the water in the oxygen giving tube, will become impregnated with an acid (apparently the nitrous); whilst that in the hydrogen giving tube, will be found to hold in solution an alkali, which in certain cases has appeared to be fixed.*

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* Mr. Nicholson, Mr. Carlisle, and Mr. Cruickshank.

† D.

‡ Original experiment, D.

From some experiments it would appear probable that the quantities of hydrogen produced in series are small, and the quantities of alkali great, in proportion as the surfaces of contact of the least oxydable metals with the water are more extended.†

All the oxygenated solutions of bodies possessing less affinity for oxygen than nascent hydrogen, are decomposed when exposed to the action of the metal occupying the place of the least oxydable part of a series in the compound circle.

Thus sulphur may be produced from sulphuric acid; and copper and other metals precipitated in the metallic form, from their solvents.‡

But little knowledge has yet been obtained concerning the chemical changes taking place in the second class of galvanic batteries. But from several experiments it would appear that they are materially different in the laws of their production from those taking place in the first class.

Thus, when single metallic wires with water, are placed as series in powerful batteries of the second order, the influence producing oxygen seems to be transmitted by the point, in the place of that part of the plate which was apparently incapable of undergoing oxydation ; whilst the hydrogen is evolved from that point where the oxydating part of the primary series appeared to exist.*

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* Mr. Cruickshank, the first discoverer of the galvanic production of alkali, supposes that the hydrogen wire in common water generates ammoniac. Perhaps the presence of muscular fibre is connected with the production of fixed alkali in the experiment detailed in the text.

† Original experiment, D.

‡ Mr. Nicholson, Mr. Cruickshank, and Mr. Henry, Jun.

6. The agency of the galvanic influence, which occasions chemical changes, and communicates electrical changes, is probably, in some measure, distinct from that agency which produces sparks, and the combustion of bodies.

The one appears, (all other circumstances being similar) to have little relation to surface in compound circles, but to be great in some unknown proportion, as the series increase in number. The intensity of the other seems to be as much connected with the extension of the surfaces of the series as with their number.

Thus, though eight series composed of plates of zinc and copper about ten inches square, and of cloths of the same size moistened in duluted muriatic acid, give sparks so vivid as to burn iron wire, yet the shocks they produce are hardly sensible, and the chemical changes indistinct.† Whilst twenty-four series of similar plates and cloths about two inches square, which occasion shocks and chemical agencies more than three times as intense, produce no light whatever.

7. A measure of the intensity of power in galvanic batteries producing chemical changes, may be derived from the quantity of gas it is capable of evolving, from water, in a given time ; or from the length of the fluid chain through which it can be transmitted. For the same law of diminution of activity that was applied to single circles in 4, page 200, may be likewise applied to compound circles.

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* D.

† Fourcroy, Vauquelin, and Thenaud.

The general relative process of different batteries may be ascertained by connecting them in opposite orders, so as to produce a certain annihilation of power. For in all cases when the most oxydable part of one series is placed opposite to the same part of another equal series, and connected with it by means of a fluid, the galvanic agencies of both are destroyed.

IV. General observations.

1. From a valuable experiment lately made,* it appears, that when common electricity is passed through water, by means of two very fine metallic points, chemical changes are effected by it similar to those occasioned by the transmission of the galvanic influence.†

This fact singly, presents a very strong analogy between galvanism and the common electrical influence, and when compared with the other facts, it amounts almost to a demonstration of their identity.

On this theory, it seems most probable, that all the different galvanic phænomena owe their existence to electricity, excited in the different arrangements, in consequence of a change in the electrical capacity of such of their parts as undergo chemical action, this action being always connected with alterations in the surfaces, and conducting powers of bodies.

The circulation of electricity in galvanic circles, from its different points of excitation, appears to depend, in a great measure, upon certain specific attractions for it in the different conductors inexplicable by known laws.

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* By Dr. Wollaston.

† [Dr. Wollaston found that a solution of sulphate of copper and of corrosive sublimate was each decomposed by common electricity, in the same manner as by Voltaic;—the metal was precipitated at the wire connected with the negative conductor:—in the instance of water, the result was different; from the extremity of each wire the two constituent gases were disengaged.—Vide Experiments on the Chemical Production and Agency of Electricity. By William Hyde Wollaston, M.D., F.R.S. Phil. Trans. 1801.]

2. In all cases of simple galvanic action, negative and positive electricity, as respectively exhibited by their de-oxydating and oxydating influences, after being once excited, can be multiplied by a certain alternation of surface.

Thus in the circle with zinc, iron, and water, in which as was stated in page 202, the zinc oxydates, and the iron undergoes no change, if a drop of water be placed on an insulated surface of the iron, it will rapidly act upon it, and produce red oxyde,—whereas if it be placed upon a similar surface of the zinc, it will undergo very little change.*

This fact will, perhaps, in some measure lead to an explanation of the cause of the accumulation of galvanism in compound circles. For in those circles, all the series are so constituted, as to produce a perfect correspondence between the electricity excited by chemical action, and that produced by compensation.

3. The general chemical agency of galvanism is at present involved in obscurity. The facts relating to the separate production of oxygen and hydrogen, acid and alkali in water, are totally incommensurable with the usually received theory of chemistry; and even supposing that the appearance of the two last of these bodies is connected with the presence of atmospheric air, it is still extremely difficult to conceive, that either oxygen or hydrogen can pass in an invisible form through fluids or organic bodies. Common physical facts present us with no analogies sufficiently distinct to enable us to reason on this subject; and the eluci-

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* D.

dation of it will probably be connected with perfectly new views of corpuscular action.

4. The appearance of galvanic action in living matter, particularly in the torpedinal organ, leads to curious inquiries. Chemical changes are perpetually going on in different parts of the living body, which must be connected with alterations in their states of electricity; and organized beings contain all the substances requisite for forming species of galvanic arrangements.

These circumstances, combined with the facts of the production of muscular contraction by common galvanism, and the dependence of irritability and even life, upon the oxygenation of the blood, afford analogies which render it probable that some phænomena similar to the galvanic phænomena, may be connected with muscular action, and other processes of life. These analogies, however, at present are very indistinct, and they ought to be considered of importance only so far as they are likely to lead to the discovery of new instruments of experimental investigation.

CONCLUSION.

The relations of galvanism to the different branches of physical science, are too numerous and too extensive to be connected with the preceding details; and, although in their infancy, they will probably long constitute favourite subjects of investigation amongst philosophers, and become the sources of useful discoveries.

The new galvanic facts have given an importance to the science, sufficient to render it interesting, and to ensure its progression. The spirit of inquiry is awakened in the public mind, and it is difficult to imagine the existence of causes capable of destroying it.

Galvanism may be pursued with greater facility than most of the other sciences; it requires less time and attention; it is less connected with manual labour, and the most delicate organs are the best fitted for performing and observing its operations.

The instruments required for galvanic experiments are few, and but little expensive. A battery composed of fifty plates, when arranged with chemical agents, forms a combination sufficiently powerful for common experiments. With such a combination, a few glass tubes having gold wires attached to them, and a gold-leaf electrometer, investigations may be pursued, and principles discovered, extending not alone to the laws of dead matter, but even to those of animated nature.

If to render galvanism a popular study, it were necessary to prove that it bore relations to the common wants of life, it might be stated that its agencies are likely at some period to become useful in the arts. When our galvanic instruments are rendered more perfect and more powerful, we may be readily enabled by means of them to procure the pure metals; and to form immediately from their elements, nitrous acid and alkali. The connexion of galvanism with philosophical medicine is evident. The electrical influence in its common form, as excited by machines, has been employed with advantage in the cures of diseases; in a new state of existence it may possibly be possessed of greater and of different powers.

But independent of the immediate applications of this science, much is to be hoped from the elucidations which it may bestow upon the kindred sciences. And a discovery so important as to excite our astonishment, cannot fail of becoming at some period useful to society. All the different branches of human knowledge are intimately connected together, and theoretical improvements cannot well be made in them without being accompanied by practical advantages.

Royal Institution,
Sept. 1, 1801.

AN ACCOUNT OF A METHOD OF CONSTRUCTING SIMPLE AND COMPOUND GALVANIC COMBINATIONS WITHOUT THE USE OF METALLIC SUBSTANCES BY MEANS OF CHARCOAL AND DIFFERENT FLUIDS.*

1. If a piece of well burned charcoal be brought in contact at one of its surfaces with a portion of water, and at another surface with a portion of nitric acid, a simple galvanic combination will be formed when the two fluids are connected together. And the powers of it are demonstrated by its agencies upon the limbs of frogs, and by its effects upon the organs of sense.

2. A compound galvanic combination, or a galvanic battery may be formed from a number of series, composed of the same substances, but in this case the fluid elements of each series not being immediately in contact, must be connected with similar elements in other series in an order of regular alternation, such as water, charcoal, acid; water, charcoal, acid; and so on.

3. The best mode that has yet occurred of constructing galvanic batteries with charcoal is by means of a number of glasses which are made to contain alternately nitrous acid and water, and which are connected in pairs by means of moistened cloth. The pieces of

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[* From Journals of the Royal Institution, vol. i.]

charcoal used are made from very dense wood, such as box or lignum vitæ; and in this case the fluids will not penetrate into them by capillary attraction much beyond the places of their primary contact. Their forms are those of arcs, so that each piece connects together two glasses; but in instances where single pieces of charcoal cannot be obtained of the proper shape, two long and thin slips may be fastened together by silk, so as to form the angle necessary to their insertion into the glasses.

4. Twenty series in a battery of this kind produce sensible but feeble shocks, and when a single metallic series with a gold wire and two glasses of water is substituted for one of the primary series, hydrogen is given out by the metallic point in the glass of water in the place of the acid, whilst oxygen is evolved from the point in the other glass.

5. In the galvanic batteries with charcoal, sulphuric acid may be substituted for nitric acid; and solution of sulphuret of potash for the water; without any material alteration in the nature of the agency; the solution of the sulphuret indeed seems, in some measure, to increase its intensity, and combinations containing this substance, dense charcoal and concentrated nitric acid, appear to be superior in activity to similar combinations containing copper, and the same fluid elements, and to be nearly equal to those composed of zinc, silver and water.

January 9, 1802.

AN ACCOUNT OF SOME EXPERIMENTS ON GALVANIC ELECTRICITY MADE IN THE THEATRE OF THE ROYAL INSTITUTION.*

The apparatus employed in these experiments was composed of 150 series of plates of copper and zinc of 4 inches square, and 50 of silver and zinc of the same size. The metals were carefully cemented into four boxes of wood in regular order, after the manner adopted by Mr. Cruickshank, and the fluid made use of was water combined with about $\frac{1}{100}$ part of its weight of nitric acid.†

The shock taken from the batteries in combination by the moistened hands, was not so powerful but that it could be received without any permanently disagreeable effects. Charges were readily communicated by means of them to coated jars, and to a battery; but in this case the effects produced by the electricity were much less distinct than in the case of immediate application.

When the circuit in the batteries was completed by means of small knobs of brass, the spark perceived was of a dazzling brightness, and in apparent diameter at

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[* From Journals of the Royal Institution, vol. i.]

† Messrs. Van Marum et Pfaff, Journal de Chemie par Van Mons, have attempted to show, that acids are less efficacious than muriate of ammonia in increasing the power of the pile; but their experiments were made with cloths, a case in which the series can only be constructed slowly, and where, when they are numerous, the acid in those first formed must be wholly or in a great measure decomposed, before the last are put together. To those who have been accustomed to operate with boxes, troughs, or glasses in which the communication by the fluids is very speedily effected, there can be no doubt of the superiority of the nitric and muriatic acids over muriate of ammonia, muriate of soda, and the alkalies in increasing all the sensible galvanic effects.

least $\frac{1}{8}$ of an inch. It was perceived only at the moment of the contact of the metals, and it was accompanied by a noise or snap.

When instead of the metals, pieces of well-burned charcoal were employed, the spark was still larger and of a vivid whiteness, an evident combustion was produced, the charcoal remained red hot for some time after the contact and threw off bright corruscations.

Four inches of steel wire $\frac{1}{110}$ of an inch in diameter, on being placed in the circuit became intensely white hot at the point of connection, and burnt with great vividness being at the same time red throughout the whole of their extent.

Tin, lead, and zinc, in thin shavings were fused and burnt at their points of contact in the circuit, with a vivid light and with a loud hissing noise. Zinc gave a blue flame,·tin a purplish, and lead a yellow flame violet at the circumference.

When copper leaf was employed it instantly inflamed at the edges with a green light and vivid sparks, and became red hot throughout the whole of its diameter when it did not exceed four inches.

Silver leaf gave a vivid light, white in the centre and green towards the outline, with red sparks or corruscations. Platina in thin slips, when made to complete the circuit, became white hot, and entered into fusion, and gave scintillations at the edges; but whether any part was converted into oxyde could not be accurately determined.

When gold leaf, attached by gum-water to white paper was burnt by the spark, the light was of a bright yellow and the noise comparatively loud; the gold was converted into an oxyde of a purplish brown colour, which firmly adhered to the paper, and by regulating the course of the spark by means of the communicating wire, letters and figures were traced by the combustion, which appeared semi-transparent when exposed to the light.

When the galvano-electric spark was taken by means of two pieces of charcoal partially covered with cotton, the cotton was readily inflamed; whether in its simple state, or sprinkled over with resin or sulphur.

Fulminating mercury and gunpowder were deflagrated by means of the communication of charcoal; and hydrogen and the compound inflammable gases, were readily made to burn when simply in contact with the atmosphere and to detonate when mixed with oxygen.

A few only of these results have any claim to originality. On the phenomena of the combustion of bodies by galvanism we have been already furnished with many striking experiments, by our own countrymen, and by the German and French philosophers. And after the path is once discovered in researches of this kind, to pursue it requires but little ability or exertion. An account of common facts, under new circumstances, particularly when they are accompanied by striking phenomena, can however never be wholly useless; and it sometimes gives a novel interest to the subject, and tends to awaken curiosity.

ACCOUNT OF SOME EXPERIMENTS MADE IN THE LABORATORY OF THE ROYAL INSTITUTION, RELATING TO THE AGENCIES OF GALVANIC ELECTRICITY, IN PRODUCING HEAT, AND IN EFFECTING CHANGES IN DIFFERENT FLUID SUBSTANCES.*

1. It has been shown, by a very interesting experiment made in France, by Messrs. Fourcroy, Vauquelin, and Thenard, that the power of galvanic batteries, containing large plates, to ignite metallic substances, is much greater than that of batteries composed of an equal number of small plates; though their agencies upon water, and upon the human body, are nearly the same.

In examining the circumstances of the action of a galvanic apparatus or trough, constructed in the Royal Institution, and containing twenty series of plates of copper and zinc, square, and thirteen inches in diameter, I observed that the same relations between chemical agency and the production of galvanic electricity existed as in other cases. When pure water was used for filling the cells, the sparks, as well as the shocks, were extremely indistinct, and the battery was capable of igniting only about a line of iron wire of $\frac{1}{170}$ of an inch in diameter. With solution of muriate of soda it acted better, and dilute nitric acid was still more efficacious. With this last substance, it became capable of rendering white-hot three inches of the iron wire of $\frac{1}{110}$, and of causing two inches to enter into fusion.

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* [From Journals of the Royal Institution, vol. i.]

In comparing the effects produced by a solution of nitrous acid, of the specific gravity of 1·4, in about sixty parts of water, with those occasioned by a concentrated solution of carbonate of potash, the acid was found to produce by much the greater intensity of action, which can hardly be ascribed to any other cause than its chemical agency; for, with regard to conducting power, it appeared very much inferior to the other solution. There is every reason to believe, that with pure water, that is, water deprived of air and of all saline substances, no action would be produced in this battery. I was unable to ascertain the fact by direct experiment; but I found repeatedly, that a pile, composed of thirty-six series of square plates of copper and zinc, of five inches in diameter, lost its activity in nitrogen and hydrogen gases, in about two days; and it was constantly restored by common air, and rendered more intense by oxygen gas.

2. When the galvanic battery, with large plates, was in full action, it was found that a wire of $\frac{1}{80}$ of an inch in diameter, and two feet long, when placed in the circuit, was rendered so hot, as to cause a small quantity of water, brought in contact with it, speedily to boil. It continued warm for many minutes; and by an occasional momentary interruption and completion of the circle, the heat was permanently kept up. When three or four inches of the wire of $\frac{1}{110}$ were placed in any part of the conducting chain, they continued red-hot for more than a minute; and by a succession of interruptions and contacts, they were kept partially ignited for five or six minutes. When that part of the communicating chain containing the small wire was

introduced into a small quantity of ether, alcohol, or oil, the fluid soon became warm; and olive oil, the only substance that was exposed for a sufficient time, was made to boil.

3. When two small pieces of well-burned charcoal, or a piece of charcoal and a metallic wire, were made to complete the circle in water, vivid sparks were perceived, gas was given out very plentifully, and the points of the charcoal appeared red-hot in the fluid for some time after the contact was made; and as long as this appearance existed, elastic fluid was generated with the noise of ebullition. The *sensible* phenomena were nearly the same with the volatile and fixed oils, ether, and alcohol; and by means of charcoal, the spark could be produced in concentrated and sulphuric and nitric acids, which are amongst the best of the less perfect conductors.

The gases produced from different fluids by the galvano-electric spark were examined; and as the results were, in most cases, what might have been expected from theory, the analysis of them was not made with very minute attention.

When water was acted upon by sparks taken from two pieces of charcoal, the elastic products evolved were about $\frac{1}{8}$ of carbonic acid, $\frac{1}{8}$ of oxygen, and the remainder an inflammable gas, which required a little more than half its volume of oxygen for its combustion. With gold and charcoal, the gold being on the zinc side, the gas produced appeared to be chiefly a mixture of oxygen and hydrogen, for it diminished $\frac{7}{10}$ by the electric spark.

The gas disengaged from alcohol, the spark being taken by gold connected with the zinc end and charcoal, was a mixture of nearly two parts of oxygen and eleven parts of inflammable gas, which appeared to be light hydro-carbonate.

Ether, in the same method of operating, gave four parts of oxygen and twelve parts of inflammable gas.

From sulphuric acid, oxygen, and hydrogen, were produced very rapidly, (the oxygen being more than sufficient for the saturation of the hydrogen by combustion,) and the acid became blue.

The gas from nitric acid detonated with great violence by the electric spark, and the residuum was oxygen mixed with a little nitrogen.

The products from the acids, there is every reason to believe, were evolved chiefly in consequence of the decomposition of the water they contained. And, in operating upon these substances, as well as upon pure water, a portion of the elastic fluid must have been produced at the time of the silent transmission of the electricity, during the momentary interruption of contact. The apparent ignition of the charcoal in the different fluids depended probably, in some measure, upon its being surrounded at the moment of contact by globules of gas, which prevented the heat, produced at the points of it, from being rapidly carried off by the fluid.

When the spark was taken by means of iron wires, in phosphorus rendered fluid by heat under a stratum of water, permanent gas was produced from it, but in a quantity too small to be examined, after a process that continued an hour. I purpose to repeat the experiment with conductors of dry charcoal.

4. When gold wires, connected with the ends of the battery, were made to act upon fluids in the common method of communication, being placed at a distance from each other, it was found that the rapidity of the evolution of the gases was much more influenced by the

conducting power of the fluid than it is in common cases with small plates. In comparing the action of a battery of twenty plates, of five inches in diameter, upon sulphuric acid, nitric acid, and various saline solutions, with that of the large battery, it was observed in several experiments, that the gas was disengaged much faster and in larger quantities from the wires connected with the large plates, whilst the action of the two arrangements upon water was nearly the same. This fact, combined with other facts of the same kind, seems to show, that the quantity of electricity excited in the arrangements with large surfaces is much greater than that produced in those with small surfaces; and that it is capable of passing with facility through the more perfect conductors, whilst, from the nature of the series, its circulation is impeded, comparatively, to a great extent, by imperfect conductors; a conjecture that has been already formed by different philosophers.

5. As the great quantity of electricity made to circulate through perfect conductors, by means of the larger apparatus, increases their affinity for oxygen more perhaps than any known agent, and as charcoal by means of it can be rendered white-hot, and kept in constant combustion in oxygen gas or atmospherical air, I thought of trying the effects of the electrical ignition of this substance upon muriatic acid gas confined over mercury.

This experiment was made by means of a small glass tube,* containing a slip of platina hermetically sealed into it, and having a piece of charcoal attached to its lower extremity: the communication was effected by means of iron wires, and the charcoal was made white-hot by successive contacts continued for nearly two hours. At the end of this time, the muriatic acid gas had diminished a very little in volume; much white matter had formed upon the charcoal, which was not sensibly consumed. When the gas was examined, three-fourths of it were instantly absorbed by water, and the remainder proved to be inflammable. The process was repeated three times; and when the spark was most vivid, a white cloud was always perceived at the moment of its production. I am inclined to attribute this phænomenon, and the other phænomena, to the decomposition of the water held in solution in the gas, by the charcoal and the mercury adhering to it; and the white matter was probably muriate of mercury. The acid gases are rapidly absorbed by charcoal; and this substance, when well made, will take up more than thirty times its volume of muriatic acid gas; so that in the process of ignition a part of the water and of the acid must have been acted upon in a very condensed state.

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* For a description of this apparatus, see p. 220.

The want of success in this experiment, the results of which are very similar to those obtained by Mr. Wm. Henry in his trials with common electricity, prevented me from carrying on the process upon fluoric acid gas, as I had at first intended. Many of the compound gases that are decomposable by heated charcoal, might probably, however, be analysed in a very simple manner, by means of the ignition of that substance by galvanic electricity; and this mode of operating may be conveniently applied, for ascertaining the relations of the affinities of charcoal for the constituent parts of compound gases at very high temperatures.

Apparatus for taking the galvanic-electrical spark in fluids and aëriform substances.

Fig. 1.

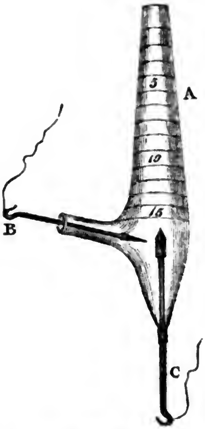

Fig. 2.

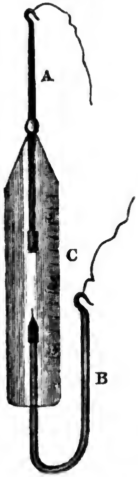

Fig. 1 represents the apparatus for taking the spark in fluids. A is a tube graduated to grain measures. C is a platina wire, hermetically sealed into the tube; and having a piece of charcoal attached to its top. B is a moveable platina wire, having charcoal at its top; the effect is produced by making the contact between the pieces of charcoal. In cases when the fluids are very imperfect conductors, the wires may be used without the charcoal.

Fig. 2 represents the apparatus for taking the spark in gases; it is used over mercury. A and B are the communicating platina wires, to which the charcoal is fastened; and C is the graduated tube in which the gas is acted upon.

OBSERVATIONS RELATING TO THE PROGRESS OF GALVANISM.

I. *On the formation of galvanic combinations, composed wholly of animal substances.*[*]

Professor Aldini, the nephew of Galvani, who is at present[†] in this country, has lately confirmed the experiments made long ago by Galvani, Volta, and other philosophers, on the production of muscular contractions, by combinations, consisting wholly of animal substances, and has elucidated them by various new facts.

Galvani prepared a frog in such a manner, that the legs were connected with the body, only by means of the sciatic nerve; and, in this case, he found the muscular contractions were produced by bringing the muscles of the legs in contact with the upper part of the body.[‡]

Volta having laid bare the muscles and the sciatic nerve in the leg of a frog, just separated from the animal, introduced them into two vessels filled with water, in such a manner, that the muscles were in one glass, and the nerve in the other. He connected the two glasses together, by means of his fingers, when a strong contraction was produced in the limb.[§]

Humboldt placed the prepared leg of a very vivacious frog upon a plate of glass, and made a contact between the sciatic nerve and the muscles of the foot, by means of a piece of muscular flesh. At the moment of the contact, muscular action was produced, and the experiment was often repeated with success.*

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[*] [From Journals of the Royal Institution, vol. i.]

[†] [The year 1802.]

[‡] Humboldt sur le Galvanisme, p. 27.

[§] Idem, p. 29.

M. Aldini has succeeded in causing contractions in the limbs of frogs, not only by bringing their nerves and muscles in contact with each other, in various modes; but likewise by placing them in contact with the nerves and muscles of warm blooded animals, just deprived of life. One of the most singular of his experiments is this: of two persons, one holds in his hand the lower muscles of the prepared leg of a frog, and the other touches with his fingers the spinal marrow of an animal recently killed. The unoccupied hands are moistened and connected with each other; and the sciatic nerve in the leg of the frog brought in contact with the bared abdominal muscles of the warm blooded animal. At the moment that the circuit is completed, the leg is agitated by strong contractions.

In considering these curious phænomena, it is difficult to account for them, except on the supposition that the animal organs are capable, in certain cases, of exerting an action similar to the metals, in producing galvanic electricity. Living animal bodies, in fact, follow the metals and charcoal, in the order of their conducting powers; they are composed of solids and fluids. And all the analogies on the subject tend to prove, that to form galvanic combinations, nothing more is necessary than the contact of solids and fluids possessed of different conducting powers, and capable of exerting chemical action on each other.

In most cases when muscular contractions are produced in animal organs, by the application of an arc composed of two metals, or of one metal and different fluids, the circulation of the electricity must be supposed to be determined by the action of the inorganic bodies. But when contractions are produced by a single metal, communicating with the organs only by means of water,* the impulse of the electricity must be attributed to the animal substances; for the arc being simple, and connected at both ends with a similar body, forms only one element of a galvanic combination, of which water is the efficient part: and it can act only as a simple conductor.

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* Op. cit. p. 31.

The galvanic power of the artificial animal combinations is evidently much feebler, and more transient than that of the metallic combinations; silver and zinc will produce contractions in the muscles of a frog, many hours after it has been insensible to the action of either of them separately used: and, in this case, the effect must be attributed simply to the passage of electricity through the irritable parts; for it takes place whatever be the form of the application.

The muscles and nerves appear to be the exciting parts in animal combinations; but as yet their states of electricity, with regard to each other, have not been ascertained. By connecting a very feeble metallic combination, with a very active animal combination, in two different ways, this problem might perhaps be solved. If, for instance, with an arc of copper and silver, connected with the nerves and muscles in the leg of a frog, by means of water, the action was much stronger when the copper was opposite to the muscle and the silver to the nerve, than in the contrary case; it would be reasonable to conclude, that the nerve bore the same relation to the muscle, as the copper to the silver, i. e. that the nerve was positive, and the muscle negative, &c.

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* The experiment on the production of muscular contraction, by the application of two portions of water, in contact with a single metal, to the organs, was first made by Galvani, and confirmed by Aldini and Humboldt. One form of it, which I have several times employed with success, is this: A piece of silver is made to connect together two glasses, filled with pure water; the leg of a frog, deprived of the skin, is suspended by a bit of silk, in such a way, that the foot and sciatic nerve are nearly parallel. On bringing the muscle in contact with one portion of water, and the nerve in contact with the other, the contraction of the limb is produced.—D.

All the facts that we are acquainted with on the subject of galvanism, tend to show, that the same substances which form simple galvanic combinations, are capable when multiplied and alternated with each other, in the proper order, of forming a galvanic battery. In consequence, however, of the susceptibility of animal substances to undergo a change, from the feebleness of the action and other circumstances in the experiment just detailed, it is probable that it will be very difficult, if not impossible, to accumulate galvanic electricity by means of arrangements composed of separate animal organs.* In the torpedo and gymnotus electricus the electrical instrument is composed wholly of living matter, and its activity is related to the general functions of the animal: and, in the case of the galvanic action of the nerves and muscles of frogs, and warm blood animals, the effect is apparently connected with some remains of vitality; which, as there is great reason to believe, would disappear during the time required for forming compound galvanic combinations.

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* I attempted to form a galvanic battery, by combining in a circle, upon a plate of glass, ten newly prepared legs of frogs, having the sciatic nerve bared, with drops of water; in the order of muscle, nerve, water; muscle, nerve, water, and so on: but no effect was produced on breaking or completing the circle, by means of one of the legs. When a silver wire was made part of the circle, contractions were produced in the two legs which were nearest to it; but the others were not affected. When a little nitrous acid was added to the water, four of the legs contracted strongly with the silver; but there was no effect with the animal substances alone. D.

II. *On the production of muscular contractions in the parts of warm blooded animals after death by the galvanic battery.*

MM. Vassali, Eandi, Giulio, and Rosi*, have succeeded in producing contractions in the heart, and arterial system, after death by connecting them with the galvanic battery.

The heart loses its susceptibility to the galvanic stimulus very soon, but the muscular organs, which are connected with large nerves, are capable of being made to contract for a considerable time.

By connecting the pectoral muscles with one end of the pile, and the par vagum and sympathetic nerves, at their origin, with the other end, very powerful muscular action was produced, which caused the phænomena of expiration and inspiration. On the first view of these experiments, we might be induced to hope for some advantages in the application of galvanism in cases of drowning, strangling, &c.; but when we consider that the contractions of most of the muscles, the actions of which are subservient to the vital functions, cannot be produced without laying bare large nerves, our expectations will be but moderate.

III. *On the galvanic batteries, said to be formed without the use of humid substances.*

In No. 9, An. xi. of the Magazine Encyclopédique, may be found the following notice:—

"M. Guyton, Member of the National Institute, and

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* Journal de Physique, Vendémiaire, An. xi.

Director of the Polytechnic School, read, at the sitting of the National Institute of the 25th of August, a memoir entitled, 'Researches on the pile of Volta' by MM. Hachette et Desormes, Professor in the Polytechnic School.

"This memoir contains two important facts which may be expected to throw great light on the theory of electricity. The first is, that an insulated electrical column, or Nairne's electrical machine, insulated, that is, communicating only with the air, is an inexhaustible source of electricity. The second fact is, that many dry and solid substances, such as pure starch, and the powder of different salts, are capable of occupying the place of the moist substance, in the pile of Volta, and that, in consequence of this discovery, piles may be formed by the mere arrangement of different substances, which are constant and almost unchangeable sources of the electrical fluid."

It is perhaps impossible to judge accurately of the nature of the researches of the French experimenters, from this short notice; and, consequently, any observations upon it may not be found applicable to the memoir itself. It may not, however, be improper to say that there is little novelty in the first fact. It is a new expression of a truth that has been generally admitted.

The second fact, the formation of a pile by means of solid substances only, would, if confirmed, be of the greatest importance in its applications to the theory and operations of galvanic electricity: it would afford a strong argument in favour of Volta's theory of *electromotion;* and it would go far to overturn the opinion concerning the dependence of the circulation of galvanic electricity upon chemical changes.

For the purpose of examining the results of MM.

Hachette and Desormes, I constructed a pile with double plates of copper and zinc and dry powder of starch in its common state; but when twelve plates had been put together, in the order of copper, zinc, starch, and so on, no effects whatever were perceived; the pile produced no sensation on the tongue, and wires from it occasioned no change in water.

On exposing a pile, composed of copper, zinc and starch, to the atmosphere in a cold and damp cellar; it was found, after two days, to have gained a slight degree of power. On moistening the starch with a very little water, the electrical action was evolved in the same manner as when wet cloths were employed. The phænomena were the same with a combination of silver and zinc; no effects could be produced from pure dry starch.

It would be unjust to decide concerning the experiments of the French chemists till the details of them are made known;—but, in the present state of our information, we should be inclined to conceive that they have been misled by the moisture, which, in common cases, adhere very strongly to starch, and to many saline substances.

On exposing a quantity of powdered starch to the gentle heat of a sand-bath, a considerable quantity of water was speedily driven off from it. When dry, it was a perfect non-conductor of electricity; but after being exposed for some hours to a moist atmosphere, it had gained a slight degree of conducting power; which as there is every reason to suppose, was the consequence of its having absorbed moisture. The salts, the earthy substances and the solid vegetable productions, when in a state of perfect dryness, are, in fact, all non-conductors, and as such it appears impossible that they can form elements of the pile of Volta. They have, however, many of them a very strong attraction for moisture, and in common cases when exposed to the atmosphere are always more or less saturated with it. I found, some time ago, that powdered steatite, from the Lizard in Cornwall, in its crude state, when used in a small galvanic pile, instead of the moistened cloth, enabled it to act, though very feebly. But after having been gently heated, it was no longer capable of producing the effect; and in its dry state, a single stratum of it, when placed in any part of an active pile, was sufficient to destroy the circulation of the electricity.

AN ACCOUNT OF A NEW EUDIOMETER.*

THE dependence of the health and existence of animals upon a peculiar state of the atmosphere, and the relations of this state to processes connected with the most essential wants of life, have given interest and importance to inquiries concerning the composition and properties of atmospheric air.

This elastic fluid has been long known to consist chiefly of oxygen and nitrogen, mingled together, or in a state of loose combination, and holding in solution water.

A variety of processes have been instituted with the view of determining the relative proportions of the two gases, but most of them have involved sources of inaccuracy; and lately all, except two, (the slow combustion of phosphorus and the action of liquid sulphurets) have been generally abandoned.

Both phosphorus and solution of sulphuret of potash absorb the whole of the oxygen of atmospheric air at common temperatures, and they do not materially alter the volume, or the properties of the residual nitrogen; but their operation is extremely slow; and in many cases it is difficult to ascertain the period at which the experiment is completed.

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* [From Journals of the Royal Institution, vol. i.]

I have lately employed as an eudiometrical substance, the solution of green muriate, or sulphate of iron impregnated with nitrous gas; and I have found that it is in some respects superior to many of the bodies heretofore used, as it rapidly condenses oxygen without acting upon nitrogen, and requires for its application only a very simple and a very portable apparatus.

This fluid is made by transmitting nitrous gas through green muriate, or sulphate of iron, dissolved to saturation in water.* As the gas is absorbed, the solution becomes of a deep olive brown, and when the impregnation is completed, it appears opaque, and almost black. The process is apparently owing to a simple elective attraction; in no case is the gas decomposed; and under the exhausted receiver it assumes its elastic form, leaving the fluid with which it was combined unaltered in its properties.

The instruments necessary for ascertaining the composition of the atmosphere, by means of impregnated solutions, consist simply of a small graduated tube, having its capacity divided into one hundred parts, and greatest at the open end; and of a vessel for containing the fluid.

The tube after being filled with the air to be examined, is introduced into the solution; and that the action may be more rapid, gently moved from a perpendicular towards a horizontal position. Under these circumstances the air is rapidly diminished; and in consequence of the dark colour of the fluid, it is easy to discover the quantity of absorption. In a few minutes the experiment is completed, and the whole of the oxygen condensed by the nitrous gas in the solution in the form of nitrous acid.

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* **Dr. Priestley first observed this process; for a particular account of it see "Researches, Chemical and Philosophical," Res. i. Div. iv. Sect. vii.**

In all eudiometrical processes with impregnated solutions, the period at which the diminution is at a stand must be accurately observed; for shortly after this period, the volume of the residual gas begins to be a little increased, and, after some hours, it will often fill a space greater by several of the hundred parts on the scale of the tube than that which it occupied at the maximum of absorption. This circumstance depends upon the slow decomposition of the nitrous acid (formed during the experiment) by the green oxyde of iron, and the consequent production of a small quantity of aëriform fluid (chiefly nitrous gas*) which having no affinity for the red muriate, or sulphate of iron produced, is gradually evolved, and mingled with the residual nitrogen.

The impregnated solution with green muriate is more rapid in its operation than the solution with green sulphate. In cases where these salts cannot be obtained in a state of absolute purity, the common or mixed sulphate of iron may be employed. One cubic inch of moderately strong impregnated solution is capable of absorbing five or six cubic inches of oxygen, in common processes; but the same quantity must never be employed for more than one experiment.

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* The decomposition of nitrous acid by solutions containing oxyde of iron at its minimum of oxydation is a very complex process. The green oxyde during its conversion into red oxyde, not only decomposes the acid, but likewise acts upon the water of the solution; and ammoniac is sometimes formed, and small portions of nitrous oxyde and nitrogen evolved with the nitrous gas.

A number of comparative experiments, made on the constitution of the atmosphere at the Hot-wells, Bristol, in July, August, and September, 1800, with phosphorus, sulphurets of alkalies, and impregnated solution, demonstrated the accuracy of the processes in which the last substance was properly employed. The diminutions given by the sulphurets were indeed always greater by a minute quantity than those produced by phosphorus, and impregnated solutions; but the reason of this will be obvious to those who have studied the subject of eudiometry. In no instance was it found that 100 parts in volume of air contained more than 21 of oxygen; and the variations connected with different winds, and different states of temperature, moisture, &c. were too small, and too often related to accidental circumstances, to be accurately noticed.

In analysing the atmosphere in different places by means of impregnated solutions, I have never been able to ascertain any notable difference in the proportions of its constituent parts. Air, collected on the sea at the mouth of the Severn, on October the 3d, 1800, which must have passed over much of the Atlantic, as the wind was blowing strong from the west, was found to contain 21 per cent. of oxygen in volume; and this was nearly the proportion in air sent from the coast of Guinea to Dr. Beddoes, by two surgeons of Liverpool.

If we compare these results with the results gained more than twenty years ago by Mr. Cavendish, from experiments on the composition of atmospherical air made at London and Kensington; considering at the same time the researches of Berthollet in Egypt and at Paris, and those of Marti in Spain, we shall find strong reasons for concluding, that the atmosphere in all places exposed to the influence of the winds, contains very nearly the same proportions of oxygen and nitrogen, a circumstance of great importance; for by teaching us that the different degrees of salubrity of air do not depend upon differences in the quantities of its principal constituent part, it ought to induce us to institute researches concerning the different substances capable of being dissolved or suspended in air, which are noxious to the human constitution; particularly as an accurate knowledge of their nature and properties would probably enable us in a great measure to guard against, or destroy their baneful effects.

ACCOUNT OF A SIMPLE METHOD OF ESTIMATING THE CHANGES OF VOLUME PRODUCED IN GASES, BY ALTERATIONS OF TEMPERATURE, AND OF ATMOSPHERIC PRESSURE, IN THE COURSE OF CHEMICAL EXPERIMENTS.*

It often happens that changes of atmospherical pressure and of temperature take place in the course of experiments on elastic fluids; and a knowledge of the alterations they produce in their volume, is essential to the precision and accuracy of the results.

In cases where chemical changes are produced, it is impossible to gain this knowledge by direct observation; and, in considering quantities, it is always useful to estimate the volumes of gases at some standard fixed upon in measures of the barometer† and thermometer.

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* [From Journals of the Royal Institution, vol. i.]

† Lavoisier's Elements, p. 406, 2d edit.

It is demonstrated by very accurate experiments, that the volumes of elastic fluids are inversely as the weights compressing them. And, consequently, the changes produced upon gases, by known changes in the atmospherical pressure, may be ascertained in a very easy manner. With regard to the effects of temperature, however, it is much more difficult to form a just estimation by means of general laws; for though the excellent experiments of Mr. Dalton,* and those of Mr.

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* Manchester Memoirs, vol. v. p. 599, Mr. Dalton says, "I have repeatedly found that 1000 parts of common air, of the temperature of 55° and common pressure, expand to 1321 parts in the manometer; to which adding 4 parts for the corresponding expansion of glass, we have 325 parts increase upon 1000 from 55° to 212°; or from 157° of the thermometric scale. As for the expansion of the intermediate degrees, which Col. Roi's experiments show to be a *slowly diminishing* one above the temperature of 57°, but which De Morveau's, on the contrary, show to be a *rapidly increasing* one in the higher part of the scale; I am obliged to allow that Col. Roi is right, though it makes, in some degree, against an hypothesis I have formed relative to the subject; but he has, certainly, however, made the diminution too great from 72° downwards, owing to his not perceiving that he actually destroyed a portion of the elastic fluid he was operating upon (aqueous vapour) in reducing its temperature so low: if his air had been previously dried by sulphuric acid, &c. he would not have found so remarkable a diminution below 72°. My experiments give for 77½° above 55°, 167 parts; for the next 77½° only 158 parts: and the expansion in every part of the scale seems to be a gradually diminishing one in ascending.

"The results of several experiments made upon hydrogenous gas, oxygenous gas, carbonic acid gas, and nitrous gas, which were all the kinds I tried, agreed with those on common air, not only in the total expansion, but in the gradual diminution of it in ascending: the small differences observed never exceeded 6 or 8 parts on the whole 325: and differences to this amount will take place in common air, when not freed from aqueous vapour, which was the situation of all my factitious gases.

"Upon the whole, therefore, I see no sufficient reason why we may not conclude, that *all elastic fluids under the same pressure expand equally by heat*—and that *for any given expansion of mercury, the correspond-*

Gay Lussac show that all the different elastic fluids, taken at equal temperatures, expand equally by heat, yet we are still ignorant of the precise expansion for increments of single degrees, or of the mode in which the form of expansion is affected by difference of pressure; or by its relations to aqueous vapour or uncombined moisture.

The calculations on this subject are consequently laborious and complicated; but it is very easy to avoid them, by recurring to comparative observations, which may be obtained in a very simple manner, by means of the manometer.

By making a given quantity of air, in contact with water at a known temperature and pressure, a standard, it is easy, in ascertaining the changes produced in it by alterations in the temperature and pressure, to determine, by the rule of proportion, the changes that have been produced from the same causes in any other quantity of gas submitted to chemical operations; or to ascertain what would be its volume at the mean height of the barometer and thermometer.

In forming the manometer for the purpose of comparison, a glass tube may be used, about sixteen inches long, and one-third of an inch in diameter, closed at one end, and curved in such a manner that its open leg is parallel to its closed end, and nearly three inches long. Its capacity is determined, and its closed leg is graduated so as to form a scale of 200 parts. The standard volume of air is confined in it by a column of water four inches long; and the height of this water is

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ing expansion of air is proportionably something less, the higher the temperature."

Mr. Gay Lussac makes the dilatation to be from 100 to 137·5 between 32° and 212°, which gives for each degree between those points $\frac{1}{480}$. See Annal. de Chimie, No. 128. p. 137.

kept equal in both legs at the different time of observation, by means of a glass tube, moveable in a perforated cork inserted in the open end, and capable of elevating the column of water in it at least an inch and half.

In employing the standard of comparison, for correcting the results of operations in which portions of elastic fluids are either absorbed or generated, it is only necessary to recur to the state of it at the beginning and end of the experiment. Thus, let n equal the quantity of elastic fluid existing after the experiment; m the volume of the standard air before the experiment; and v the volume after, as expressed in the scale of 200 parts.

Then $\frac{n\,m}{v}=x$ which is the volume the residual gas examined would occupy at such temperatures and pressures as had been at any time denoted upon the scale.

From the latest experiments that have been made,* it is probable that at the same temperatures, and under the same pressures, equal volumes of the different elastic fluids, in contact with water contain the same quantity of aqueous vapour; so that in cases when the gases examined in the comparative observations are equally saturated with water, the results must be perfectly accurate as to the relation of volume to the state of moisture; and, even supposing a difference in the degree of saturation, the error arising from this circumstance, at common temperatures, would be so small as to be inappreciable.

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* Those of Saussure and De Luc, and MM. Desormes and Clement.

OBSERVATIONS ON DIFFERENT METHODS OF OBTAINING GALLIC ACID.[*]

1. THE discoverer of the gallic acid, the celebrated Scheele, first obtained it by suffering a solution of gall-nuts to remain long exposed to the atmosphere.[†] In this case the acid is deposited upon the sides of the vessel containing the solution, and upon the film which forms on the surface; but its crystals are of a greyish brown colour, being mixed with other vegetable matter.

2. When heat is very slowly applied to powdered gall-nuts, gallic acid sublimes from them, a part of which, when the process is conducted with great care, appears in the form of small white cyrstals. This method was first employed by M. Deyeux.[‡] I have often successfully made use of it. When the operation is carried on in close vessels, the first product is a limpid fluid which has the properties of a solution of gallic acid in water, and of which the last portions are pale yellow. The crystals form in that part of the vessel where the heat is just sufficient to cause water to boil; and the process must be stopped at the moment that the crystals in the lower part of the vessel begin to melt. An Argand's lamp may be used for the application of the heat; and the silver still for caustic alkali is a proper apparatus for making the sublimation in. I have found it expedient to separate some tannin from the gall-nuts, by infusing them in a small quantity of water before they are used,

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[*] [From Journals of the Royal Institution, vol. i.]

[†] Crell's Annals.

[‡] Fourcroy, Connoissances Chemiques, tom. vii. p. 181.

as, in this case, there is less empyreumatic oil produced in the distillation.

3. M. Fiedler has lately recommended a new process for preparing the gallic acid. He mixes together a solution of gall-nuts and pure alumine; and he asserts that after some time, the alumine combines with the tannin and extractive matter of the gall-nuts; and that the gallic acid remains free in the solution, and may be obtained in crystals by evaporation.* I have employed M. Fiedler's method, but without having perfect success in the results. After pure alumine and solution of gall-nuts had been suffered to remain together in the cold for three days, being very often agitated, the filtrated liquor still gave a slight precipitate with gelatine. I boiled about half an ounce of pure alumine with a solution obtained from nearly an ounce of gall-nuts; and in this case, I obtained a liquor which gave no precipitate with a solution of isinglass, or muriate of tin; so that it contained neither tannin nor extractive matter; but it likewise contained very little gallic acid, for it gave only a very faint olive colour when mixed with a solution of oxygenated sulphate of iron. By boiling together a solution of gall-nuts and carbonate of alumine, procured from the decomposition of alum by carbonate of potash, I obtained a clear liquor free from tannin and extractive matter, which gave a deep black colour with oxygenated sulphate of iron, and which, when evaporated, furnished a mass of white opaque crystals. I suspect, however, that these crystals contained as well as gallic acid a small portion of alumine; for, when dissolved in distilled water, they rendered cloudy a solution of ammoniac.

4. I have found that when carbonate of barytes is boiled for some time with a solution of gall-nuts it affords

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* Van Mons's Journal, tom. i. p. 85.

a blue green liquor; which appears from the common tests to contain neither tannin nor extract. When diluted sulphuric acid is dropped into the green liquor, it becomes turbid, sulphate of barytes is deposited; and after filtration if the saturation of the earth be perfect, a colourless solution of gallic acid apparently pure is obtained. All the alkaline earths, whether pure or saturated with carbonic acid, have, as I have found by various experiments, a strong attraction for tannin; and are capable of combining with a certain quantity of extractive matter. When a pure earth is made to act upon gallic acid, a salt is procured having an excess of base and nearly insoluble; but when an earth, combined with carbonic acid, is exposed to the agency of gallic acid, the salt formed is soluble, and seems to possess an excess of acid.

5. Of the different methods that have been described, that of M. Deyeux is undoubtedly the most simple and least expensive. The process with carbonate of barytes may, however, be sometimes employed with advantage, particularly in cases where gall-nuts have been previously lixiviated for the purpose of obtaining tannin. There is very little mucilage in gall-nuts; in cases, however, when the presence of it is suspected in gallic acid, this substance may be freed from it, by being dissolved in alcohol and then evaporated. When in processes of evaporation, gallic acid is coloured, by being partially decomposed, a clear solution of it may be again obtained, by means of ether, which dissolves the acid without acting upon the colouring matter. This last process is, however, too expensive to be commonly applied; and it should be used only in cases when an acid is required absolutely pure.

AN ACCOUNT OF A METHOD OF OBTAINING THE SALTS OF IRON AT THE MINIMUM OF OXYDATION.*

THE sulphate, muriate, and acetate of iron at their minimum of oxydation, may be obtained in a very easy manner, by means of the artificial sulphuret of iron. When artificial sulphuret of iron is acted upon by muriatic acid or sulphuric acid in a state of dilution, or acetous acid, the sulphuretted hydrogen gas, disengaged during the process of solution, prevents any hyperoxygenated salt from being formed by the action of the atmosphere; and a clear fluid in all cases of a shade of green, is obtained, which when freed by heat from any sulphuretted hydrogen dissolved in it, gives a perfectly white precipitate with the alkaline prussiates, and is not found to alter the colour of solution of galls.

To form the least oxygenated nitrate of iron by means of the artificial sulphuret, an acid of a specific gravity not greater than 1·12 must be used, and the solution must be made without the assistance of heat. After having been freed from sulphuretted hydrogen by being boiled for a minute or two, and then filtrated, it is found similar in its colour and physical properties to the weakest solutions of the other oxygenated salts.

When the sulphate and muriate of iron, at the minimum of oxydation, are obtained in the solid form by evaporation from their solutions, they appear in regular crystals, which in each salt are a different shade of a very pale green colour; their tastes are exactly

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[* From Journals of the Royal Institution, vol. i.]

similar, being astringent, and leaving in the mouth the sensation of sweetness.

The least oxygenated nitrate of iron cannot easily be procured pure in the crystallized state, for when the solution of it is heated for any length of time, a new arrangement of its principles takes place; portions of the acid and of the water of the solution are decomposed; in consequence of which ammoniac is formed, and an oxygenated nitrate of iron with excess of base is deposited.

Amongst the salts of iron at the minimum of oxydation, I have found the muriate the most convenient for exhibiting the experiments of Proust, and in eudiometrical processes with nitrous gas (page 230). It is more soluble in water than the sulphate, and very much more soluble in alcohol.

AN ACCOUNT OF A METHOD OF COPYING PAINTINGS UPON GLASS, AND OF MAKING PROFILES BY THE AGENCY OF LIGHT UPON THE NITRATE OF SILVER. INVENTED BY T. WEDGEWOOD, ESQ. WITH OBSERVATIONS BY H. DAVY.*

White paper, or white leather, moistened with solution of nitrate of silver, undergoes no change when kept in a dark place; but on being exposed to the daylight it speedily changes colour, and after passing through different shades of grey and brown, becomes at length nearly black.

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* [From the Journals of the Royal Institution, vol. i.]

The alterations of colour take place more speedily in proportion as the light is more intense. In the direct beams of the sun, two or three minutes are sufficient to produce the full effect. In the shade, several hours are required, and light transmitted through different coloured glasses acts upon it with different degrees of intensity. Thus, it is found that red rays, or the common sunbeams passed through red glass have very little action upon it; yellow and green are more efficacious, but blue and violet light produce the most decided and powerful effects.*

The consideration of these facts enables us readily to understand the method by which the outlines or shades of paintings on glass may be copied, or profiles of figures procured by the agency of light when a white surface covered with a solution of nitrate of silver is placed behind a painting on glass exposed to the solar light; the rays transmitted through the differently painted surfaces, produce distinct tints of brown or black, sensibly differing in intensity according to the shades of the picture, and where the light is unaltered the colour of the nitrate becomes deepest.

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* The facts above-mentioned are analogous to those observed long ago by Scheele, and confirmed by Senebier. Scheele found that in the prismatic spectrum, the effect produced by the red rays upon muriate of silver was very faint and scarcely to be perceived; whilst it was speedily blackened by the violet rays. Senebier states that the time required to blacken muriate of silver by the red rays is twenty minutes, by the orange twelve, by the yellow five minutes and thirty seconds, by the green thirty-seven seconds, by the blue twenty-nine seconds, and by the violet only fifteen seconds.—Senebier sur la lumiere, vol. iii. p. 199.

Some new experiments have been lately made in relation to this subject, in consequence of the discoveries of Dr. Herschel concerning the invisible, heat-making rays existing in the solar beams, by Messrs. Ritter and Böckman in Germany, and Dr. Wollaston in England.

It has been ascertained, by experiments upon the prismatic spectrum, that no effects are produced upon the muriate of silver by the invisible heat-making rays which exist on the red side, and which are least refrangible, though it is powerfully and distinctly affected in a space beyond the violet rays, out of the visible boundary.—See Annalen der Physik Siebenten, Band 527.

When the shadow of any figure is thrown upon the prepared surface, the part concealed by it remains white, and the other parts speedily become dark.

For copying paintings on glass the solution should be applied on leather; and in this case it is more readily acted upon than when paper is used.

After the colour has been once fixed upon the leather or paper, it cannot be removed by the application of water, or water and soap, and it is in a high degree permanent.

The copy of a painting, or the profile immediately after being taken, must be kept in an obscure place. It may indeed be examined in the shade, but in this case the exposure should be only for a few minutes; by the light of candles or lamps, as commonly employed, it is not commonly affected.

No attempts that have been made to prevent the uncoloured parts of the copy, or profile, from being acted upon by light, have as yet been successful. They have been covered with a thin coating of fine varnish, but this has not destroyed their susceptibility of becoming coloured; and even after repeated washings, sufficient of the active part of the saline matter will still adhere to the white parts of the leather or paper, to cause them to become dark when exposed to the rays of the sun.

Besides the applications of this method of copying that have been just mentioned, there are many others. And it will be useful for making delineations of all such objects as are possessed of a texture partly opaque and partly transparent. The woody fibres of leaves and the wings of insects, may be pretty accurately represented by means of it; and in this case, it is only necessary to cause the direct solar light to pass through them and to receive the shadows upon prepared leather.

When the solar rays are passed through a print and thrown upon prepared paper, the unshaded parts are slowly copied; but the lights transmitted by the shaded parts are seldom so definite as to form a distinct resemblance of them, by producing different intensities of colour.

The images formed by means of a camera obscura, have been found too faint to produce in any moderate time an effect upon the nitrate of silver. To copy these images was the first object of Mr. Wedgewood, in his researches on the subject, and for this purpose he first used the nitrate of silver, which was mentioned to him by a friend, as a substance very sensible to the influence of light; but all his numerous experiments, as to their primary end, proved unsuccessful.

In following these processes, I have found that the images of small objects, produced by means of the solar microscope, may be copied without difficulty on prepared paper. This will probably be a useful application of the method; that it may be employed successfully, however, it is necessary that the paper be placed at but a small distance from the lens.

With regard to the preparation of the solution, I have found the best proportions those of one part of nitrate to about ten of water. In this case, the quantity of the salt applied to the leather or paper will be sufficient to enable it to become tinged, without affecting its composition or injuring its texture.

In comparing the effects produced by light upon muriate of silver with those produced upon the nitrate, it seemed evident that the muriate was the most susceptible, and both were more readily acted upon when moist than when dry, a fact long ago known. Even in the twilight, the colour of moist muriate of silver spread upon paper, slowly changed from white to faint violet; though under similar circumstances no immediate alteration was produced upon the nitrate.

The nitrate, however, from its solubility in water, possesses an advantage over the muriate; though leather or paper may, without much difficulty, be impregnated with this last substance, either by diffusing it through water, and applying it in this form, or by immersing paper moistened with the solution of the nitrate in very diluted muriatic acid.

To those persons not acquainted with the properties of the salts containing oxyde of silver, it may be useful to state that they produce a stain of some permanence, even when momentarily applied to the skin, and in employing them for moistening paper or leather, it is necessary to use a pencil of hair or a brush.

From the impossibility of removing by washing, the colouring matter of the salts from the parts of the surface of the copy which have not been exposed to light; it is probable that both in the case of the nitrate and muriate of silver, a portion of the metallic oxyde abandons its acid to enter into union with the animal or vegetable substance, so as to form with it an insoluble compound. And, supposing that this happens, it is not improbable, but that substances may be found capable of destroying this compound either by simple or complicated affinities. Some experiments on this subject have been imagined, and an account of the results of them may possibly appear in a future number of the journals. Nothing but a method of preventing the unshaded parts of the delineation from being coloured by exposure to the day, is wanting to render the process as useful as it is elegant.*

SOME OBSERVATIONS UPON THE MOTIONS OF SMALL PIECES OF ACETATE OF POTASH, DURING THEIR SOLUTION, UPON THE SURFACE OF WATER.†

IN dissolving some acetate of potash in distilled water, I accidently observed that some of the small pieces of that light and scaly salt which floated upon the surface of the water were agitated by very singular motions during the time of their solution; these motions were very irregular. The fragments sometimes revolved for a second or two, and then moved rapidly backwards and forwards in various directions.

The phænomenon was evidently connected with the rapidity of the process of dissolution, for as the water became saturated with salt, the motion became gradually weaker, and at last ceased altogether. The thinnest film of oil, or of ether, wholly destroyed the effect, and in several cases it did not take place, when the water that had been exposed to the atmosphere, and on which some dust had probably been deposited was employed, or when a vessel, that had not been accurately cleaned was used.

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* [Recently this method of delineation has been further cultivated, especially by Mr. Talbot in this country; and it would appear with considerable success. An account of the "Art of Photogenic Drawing" by this gentleman may be found in the Athenæum of the 9th Feb. 1839.]

† [From Journals of the Royal Institution, vol. i.]

Those pieces which were most irregular in their forms underwent by far the most rapid motions, from which it would appear that the phænomenon was in some measure owing to changes in their centre of gravity, during the solution. The projectile motions, probably, chiefly depended upon the continual descent of a current of solution of the salt in water from the agitated particle, in consequence of which, the surrounding water would press upon different parts of it with different degrees of force. I found, by means of a mercurial thermometer, that the solution of acetate of potash in water, is connected with an increase of temperature; and it is not improbable that this circumstance, may in some measure modify the effect.

AN ACCOUNT OF SOME EXPERIMENTS AND OBSERVATIONS ON THE CONSTITUENT PARTS OF SOME ASTRINGENT VEGETABLES; AND ON THEIR OPERATION IN TANNING.*

THE discovery made by M. Seguin, of a peculiar vegetable matter which is essential to the tanning of skin, and which is possessed of the property of precipitating gelatine from its solutions, has added considerably to our knowledge of the constituent parts of astringent vegetables.

Mr. Proust has investigated many of the properties of this substance; but, though his labours, and those of other chemists, have led to various interesting observa-

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[* From Phil. Trans. for 1803.]

tions, yet they are far from having exhausted the subject. The affinities of tannin have been hitherto very little examined; and the manner in which its action upon animal matter is modified by combination with other substances, has been scarcely at all studied.

At the desire of the managers of the Royal Institution, I began, in September, 1801, a series of experiments on the substances employed in the process of tanning, and on the chemical agencies concerned in it. These experiments have occupied, ever since, a considerable portion of my leisure hours; and I now presume to lay before the Royal Society an account of their general results. My chief design was, to attempt to elucidate the practical part of the art; but, in pursuing it, I was necessarily led to general chemical inquiries concerning the analysis of the different vegetable substances containing tannin, and their peculiar properties.

1. *Observations on the Analysis of Astringent Vegetable Infusions.*

The substances that have been supposed to exist most generally in astringent infusions are tannin, gallic acid, and extractive matter.

The presence of tannin in an infusion, is denoted by the precipitate it forms with the solution of glue, or of isinglass. And, when this principle is wholly separated, if the remaining liquor gives a dark colour with the oxygenated salts of iron, and an immediate precipitate with the solutions of alum and of muriate of tin, it is believed to contain gallic acid, and extractive matter.

The experiments of MM. Fourcroy, Vauquelin, and Seguin, have shown that many astringent solutions undergo a change by exposure to the atmosphere; an insoluble matter being precipitated from them. A precipitation is likewise occasioned in them by the action of heat; and these circumstances render it difficult to ascertain, with any degree of precision, the quantities of their constituent parts, as they exist in the primitive combination.

After trying several experiments on different methods of ascertaining the quantity of tannin in astringent infusions, I was induced to employ the common process of precipitation by gelatine, as being the most accurate.

This process, however, requires many precautions. The tanning principle in different vegetables, as will be seen hereafter, demands for its saturation different proportions of gelatine; and the quantity of precipitate obtained by filtration, is not always exactly proportional to the quantities of tannin and gelatine in solutions, but is influenced by the degree of their concentration. Thus, I found that 10 grains of dry isinglass, dissolved in 2 ounces of distilled water, gave, with solution of galls in excess, a precipitate weighing, when dry, 17 grains; whilst the same quantity, dissolved in 6 ounces of water, produced, all other circumstances being similar, not quite 15 grains. With more diluted solutions, the loss was still greater; and analogous effects took place, when equal portions of the same solution of isinglass were acted on by equal portions of the same infusion of galls diluted in different degrees with water; the least quantity of precipitate being always produced by the least concentrated liquor. In all cases, when the weak solutions were used, it was observed, that the residual fluid, though passed two or three times through the filter, still remained more or less turbid and opaque; so that it is most likely that the deficiency arose from the continued suspension of some of the minutely divided solid matter in the liquid mass.

The solutions of gelatine, for the purposes of analysis, should be employed only when quite fresh, and in as high a state of saturation as is compatible with their perfect fluidity. I have observed, that in cases when they approach towards the state of jelly, their power of acting upon tannin is materially altered, and they produce only a very slight precipitation. As the degree of fluidity of solutions of gelatine is influenced by their temperature, I have found it expedient, in all comparative experiments, to bring them and the astringent infusions on which they are designed to act, as nearly as possible to a common degree of heat. My standard temperature has been between 60° and 70° Fahrenheit; and the solutions of gelatine that I have used, were made by dissolving 120 grains of isinglass in 20 ounces of water.

In ascertaining the proportions of tannin in astringent infusions, great care must be taken to prevent the presence of any excess of gelatine; for, when this excess exists, I have found that a small portion of the solid compound formed is re-dissolved, and the results of the experiments otherwise affected. It is not difficult to discover the precise point of saturation, if the solution of isinglass be added only in small quantities at a time, and if portions of the clear liquor be passed through a filter at different periods of the process. The properties of these portions will indicate the quantities of the solution of gelatine required for the completion of the experiments.

That the composition of any precipitate containing tannin and gelatine may be known with a tolerable degree of precision, it is necessary that the isinglass employed in the solution, and the new compound formed, be brought as nearly as possible to the same degree of dryness. For this purpose, I have generally exposed them, for an equal time, upon the lower plate of a sand-bath, which was seldom heated to more than 150°. This method I have found much better than that of drying at the temperatures of the atmosphere, as the different states of the air, with regard to moisture, materially influence the results.

Mr. Hatchett has noticed in his excellent paper, on Zoophytes, &c.*, that isinglass is almost wholly composed of gelatine. I have found, that 100 grains of good and dry isinglass contain rather more than 98 grains of matter soluble in water. So that, when the quantity of isinglass, in any solution employed for acting upon an astringent infusion, is compared with the quantity of the precipitate obtained, the difference between them will indicate the proportion of tannin, as it exists in the combination.

After the tannin has been separated from an astringent infusion, for the purpose of ascertaining its other component parts, I have been accustomed to evaporate the residual liquor very slowly, at a temperature below 200°.† In this process, if it contains extractive matter, that substance is in part rendered insoluble, so as to fall to the bottom of the vessel. When the fluid is reduced to a thick consistence, I pour alcohol upon it. If any gallic acid, or soluble extractive matter be present, they will be dissolved, after a little agitation, in the alcohol; whilst the mucilage, if any exist, will remain unaltered, and may be separated from the insoluble extract, by lixiviation with water.

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* Phil. Trans. for 1800. p. 327.

† M. Deyeux has shewn (Annales de Chimie, tom xvii. p. 36.) that in the process of evaporating solutions of galls, no gallic acid is carried over by the water, at a temperature below that of ebullition. Many astringent infusions, however, lose a portion of their aromatic principle, even in cases when they are not made to boil; but this substance, though evident to the smell, in the water that comes over, cannot be detected by chemical reagents.

I have made many experiments with the hope of discovering a method by which the respective quantities of gallic acid and extractive matter, when they exist in solution in the alcohol, may be ascertained; but without obtaining success in the results. It is impossible to render the whole of any quantity of extractive matter insoluble by exposure to heat and air, without at the same time decomposing a portion of the gallic acid. That acid cannot be sublimed, without being in part destroyed; and, at the temperature of its sublimation, extractive matter is wholly converted into new products.

Ether dissolves gallic acid; but it has comparatively little action upon extractive matter. I have been able, in examining solutions of galls, to separate a portion of gallic acid by means of ether. But, when the extractive matter is in large quantities, this method does not succeed, as in consequence of that affinity which is connected with mass,* the greater part of the acid continues to adhere to the extract.

Alumine has a strong attraction for extractive matter; but comparatively a weak one for gallic acid.† When carbonate of alumine is boiled for some time with a solution containing extractive matter, the extractive matter is wholly taken up by the earth, with which it forms an insoluble compound; but, into this compound, some of the gallic acid appears likewise to enter; and the portion remaining dissolved in the solution is always combined with alumine.

I have not, in any instance, been able to separate gallic acid and extractive matter perfectly from each other; but I have generally endeavoured to form some judgment concerning their relative proportions, by means of the action of the salts of alumine, and the oxygenated salts of iron. Muriate of alumine precipitates much of the extractive matter from solutions, without acting materially upon gallic acid; and, after this precipitation, some idea may be formed concerning the quantity of the gallic acid, by the colour it gives with the oxygenated sulphate of iron. In this process, however, great care must be taken not to add the solution of the sulphate of iron in excess; for, in this case, the black precipitate formed with the gallic acid will be redissolved, and a clear olive-coloured fluid only will be obtained.

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* See Berthollet's Récherches, sur les Lois de l'affinité. Mem. de l'Institut National, tom. iii. p. 5.

† See Fiedler. Journal de Chimie, par J. B. Van-Mons, tom. i. p. 85.

The saline matters in astringent infusions, adhere so strongly to the vegetable principles, that it is impossible to ascertain their nature with any degree of accuracy, by means of common reagents. By incineration of the products obtained from the evaporation of astringent infusions, I have usually procured carbonate of lime and carbonate of potash.

From the different analyses, as will be seen from the results given in the following sections, I have attended chiefly to the proportions of the tanning principle, and of the principles precipitable by the salts of iron, as being most connected with practical applications.

With regard to the knowledge of the nature of the different substances, as they exist in the primitive astringent infusion, we can gain, by our artificial methods of examination, only very imperfect approximations. In acting upon them by reagents, we probably, in many cases, alter their nature; and very few of them only can be obtained in an uncombined state. The comparison, however, of the products of different experiments with each other, is always connected with some useful conclusions; and the accumulation of facts with regard to the subject must finally tend to elucidate this obscure but most interesting part of chemistry.

2. *Experiments on the Infusion of Galls.*

I have been very much assisted in my inquiries concerning the properties of the infusions of galls, by the able memoir of M. Deyeux, on galls.*

The strongest infusion of galls that I could obtain, at 56° Fahrenheit, by repeatedly pouring distilled water upon the best Aleppo galls broken into small pieces, suffering it to remain in contact with them till the saturation was complete, was of specific gravity 1·068. Four hundred grains of it produced by evaporation at a temperature below 200°, fifty-three grains of solid matter; which, as well as I could estimate by the methods of analysis that have been just described, consisted of about nine-tenths of tannin, or matter precipitable by gelatine, and one-tenth of gallic acid, united to a minute portion of extractive matter.

One hundred grains of the solid matter obtained from the infusion, left, after examination, nearly 4¾ grains of ashes, which were chiefly calcareous matter, mixed with a small portion of fixed alkali. The infusion strongly reddened paper tinged with litmus. It was semi-transparent, and of a yellowish brown colour. Its taste was highly astringent. When sulphuric acid was poured into the infusion, a dense whitish precipitate was produced; and this effect was constant, whatever quantity of the acid was used. The residual liquor, when passed through the filter, was found of a shade of colour deeper than before. It precipitated gelatine, and gave a dark colour with the oxygenated sulphate of iron.

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* Annales de Chimie, tom. xvii. p. 1.

The solid matter remaining on the filter slightly reddened vegetable blues; and when dissolved in warm water, copiously precipitated the solutions of isinglass. Mr. Proust,* who first paid attention to its properties, supposed that it is a compound of the acid with tannin; but I suspect that it also contains gallic acid, and probably a small portion of extractive matter. This last substance, as is well known, is thrown down from its solutions by sulphuric acid; and I found, in distilling the precipitate from galls by sulphuric acid, at a heat above 212°, that a fluid came over of a bright yellow colour, which was rendered black by oxygenated sulphate of iron; but which was not altered by gelatine.

Muriatic acid produced in the infusion effects analagous to those produced by sulphuric acid; and two compounds of the acid and the vegetable substances were formed: the one united to excess of acid, which remained in solution; the other containing a considerable quantity of tannin, which was precipitated in the solid form.

When concentrated nitric acid was made to act upon the infusion, it was rendered turbid; but the solid matter formed was immediately dissolved with effervescence, and the liquor then became clear and of an orange colour. On examining it, it was found that both the tannin and the gallic acid were destroyed; for it gave no precipitate, either with gelatine or the salts of iron, even after the residual nitric acid was saturated by an alkali. By evaporation of a portion of the fluid, a soft substance was obtained, of a yellowish brown colour, and of a slightly sourish taste. It was soluble in water, and precipitated the nitro-muriate of tin, and the nitrate of alumine; so that its properties approached to those of extractive matter; and it probably contained oxalic acid, as it rendered turbid a solution of muriate of lime.

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* The fact of the precipitation of solution of galls by acids was noticed by M. Dizé. See Annales de Chimie, tom. xxxv. p. 37.

When a very weak solution of nitric acid was mixed with the infusion, a permanent precipitate was formed; and the residual liquor, examined by the solution of gelatine, was found to contain tannin.

A solution of pure potash was poured into a portion of the infusion. At first, a faint turbid appearance was perceived; but, by agitation, the fluid became clear, and its colour changed from yellow-brown to brown-red; and this last tint was most vivid on the surface, where the solution was exposed to the atmosphere. The solution of isinglass did not act upon the infusion modified by the alkali, till an acid was added in excess, when a copious precipitation was occasioned.

The compound of potash and solution of galls, when evaporated, appeared in the form of an olive-coloured mass, which had a faint alkaline taste, and which slowly deliquesced when exposed to the air.

Soda acted upon in the infusion in the same manner as potash; and a fluid was formed, of a red-brown colour, which gave no precipitate to gelatine.

Solution of ammonia produced the same colour as potash and soda, and formed so perfect an union with the tannin of the infusion, that it was not acted upon by gelatine. When the compound liquor was exposed to the heat of boiling water, a part of the ammonia flew off, and another part reacted upon the infusion, so as to effect a material change in its properties. A considerable quantity of insoluble matter was formed; and the remaining liquor contained little tannin and gallic acid, but a considerable portion of a substance that precipitated muriate of tin and the salts of alumine.

When the experiment on the ebullition of the compound of the infusion and ammonia was made in close vessels, the liquor that came over was strongly impregnated with ammonia; its colour was light yellow, and when saturated with an acid, it was very little altered by the salts of iron. The residual fluid, after the process had been continued for some time, as in the other case, precipitated gelatine slightly, but the salts of alumine copiously; and it gave a tinge of red to litmus paper.

When solution of lime, of strontia, or of barytes, was poured in excess into a portion of the infusion, a copious olive-coloured precipitate was formed, and the solution became almost clear and of a reddish tint. In this case, the tannin, the gallic acid, and the extractive matter, seemed to be almost wholly carried down in the precipitates; as the residual fluids, when saturated by an acid, gave no precipitate to gelatine, and only a very slight tint of purple to oxygenated sulphate of iron.

When the solutions of the alkaline earths were used only in small quantities, the infusion being in excess, a smaller quantity of precipitate was formed, and the residual liquor was of an olive-green colour; the tint being darkest in the experiment with barytes, and lightest with that with the lime. This fluid, when examined, was found to hold in solution a compound of gallic acid and alkaline earth. It became turbid when acted on by a little sulphuric acid; and, after being filtrated, gave a black colour with the solutions of iron, but was not acted upon by gelatine.

When a large proportion of lime was heated for some time with the infusion, it combined with all its constituent principles, and gave, by washing, a fluid which had the taste of lime-water, and which held in solution a very small quantity of vegetable matter. Its colour was pale yellow, and when saturated with muriatic acid, it did not precipitate gelatine, and gave only a slight purple tinge to the solutions of the salts of iron. The lime in combination with the solid matter of the infusion was of a fawn colour. It became green at its surface, where it was exposed to the air; and when washed with large quantities of water, it continued to give, even to the last portions, a pale yellow tinge.

Magnesia was boiled in one portion of the infusion for a few hours, and mixed in excess with another portion, which was suffered to remain cold. In both cases a deep green fluid was obtained, which precipitated the salts of iron, but not the solutions of gelatine, and the magnesia had acquired a grayish-green tint. Water poured upon it became green, and acquired the properties of the fluid at first obtained. After long washing, the colour of the magnesia changed to dirty yellow; and the last portions of water made to act upon it were pale yellow, and altered very little the solutions of iron.

When the magnesia was dissolved in muriatic acid, a brownish and turbid fluid was obtained, which precipitated gelatine and the oxygenated salts of iron. So that there is every reason to believe, that the earth, in acting on the astringent infusion, had formed two combinations; one containing chiefly gallic acid, which was easily soluble in water; the other containing chiefly tannin, which was very difficultly soluble.

Alumine boiled with the infusion became yellowish-gray, and gave a clear white fluid, which produced only a tinge of light purple in the solutions of iron.

When the earth* was employed in very small quantity, however, it formed an insoluble compound only with the tannin and the extract; and the residual liquor was found to contain a gallate of alumine with excess of acid.

The oxydes of tin and of zinc, obtained by nitric acid, were boiled with separate portions of the infusion for two hours. In both cases, a clear fluid, which appeared to be pure water, was obtained, and the oxydes gained a tint of dull yellow. A part of each of them was dissolved in muriatic acid. The solution obtained was yellow: it copiously precipitated gelatine, and gave a dense black with the salts of iron. Mr. Proust,† who first observed the action of oxyde of tin upon astringent infusions, supposes that portions of tannin and gallic acid are decomposed in the process, or converted, by the oxygen of the oxyde, into new substances. These experiments do not, however, appear to confirm the supposition.

M. Deyeux observed, that a copious precipitation was occasioned in infusion of galls, by solutions of the alkalies combined with carbonic acid. Mr. Proust had supposed that the solid matter formed is pure tannin, separated from its solution by the stronger affinity of the alkali for water; and he recommends the process, as a method of obtaining tannin.

In examining the precipitate obtained by carbonate of potash fully combined with carbonic acid, and used to saturation, I have not been able to recognise in it the properties which are usually ascribed to tannin; it is not possessed of the astringent taste, and it is but slightly soluble in cold water, or in alcohol. Its solution acts very little upon gelatine, till it is saturated with an acid, and it is not possessed of the property of tanning skin.

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* Mr. Fiedler, I believe, first observed the action of alumine upon tannin. Van-Mons' Journal, tom. i. p. 86.

† Annales de Chimie, tom. xlii. p. 69.

In various cases, in which the greatest care was taken to use no excess, either of the astringent infusion or of the alkaline solution, I have found the solid matter obtained possessed of analogous properties; and it has always given, by incineration, a considerable portion of carbonate of potash, and a small quantity of carbonate of lime.

The fluid remaining after the separation of the precipitate was of a dark brown colour, and became green at the surface, when it was exposed to the air. It gave no precipitate to solution of gelatine, and afforded only an olive-coloured precipitate with the salts of iron.

When muriatic acid was poured into the clear fluid, a violent effervescence was produced; the fluid became turbid; a precipitate was deposited, and the residual liquor acted upon by gelatine and the salts of iron, in a manner similar to the primitive infusion.

M. Deyeux, in distilling the precipitate from infusion of galls by carbonate of potash, obtained crystals of gallic acid. In following his process, I had similar results; and a fluid came over, which reddened litmus-paper, and precipitated the salts of iron black, but did not act upon gelatine.

When the precipitate by carbonate of potash was acted upon by warm water, applied in large quantities, a considerable portion of it was dissolved; but a part remained, which could not in any way be made to enter into solution; and its properties were very different from those of the entire precipitate. It was not at all affected by alcohol: it was acted on by muriatic acid, and partially dissolved; and the solution precipitated gelatine and the salts of iron. It afforded, by incineration, a considerable portion of lime, but no alkali.

In comparing these facts, it would seem that the precipitate from infusion of galls, consists partly of tannin and gallic acid united to a small quantity of alkali, and partly of those vegetable matters combined with calcareous earth; and it will appear probable, when the facts hereafter detailed are examined, that both the potash and the lime are contained in these compounds in a state of union with carbonic acid.

The solutions of carbonate of soda and of carbonate of ammonia, both precipitated the infusion of galls in a manner similar to the carbonate of potash; and each of the precipitates, when acted upon by boiling water, left a small quantity of insoluble matter, which seemed to consist chiefly of tannin and carbonate of lime.

The entire precipitate by carbonate of soda produced, when incinerated, carbonate of soda and carbonate of lime. The precipitate by carbonate of ammonia, when exposed to a heat sufficient to boil water, in a retort having a receiver attached to it, gave out carbonate of ammonia, (which was condensed in small crystals in the neck of the retort) and a yellowish fluid, which had a strong smell and taste of this volatile salt. After the process of distillation, the solid matter remaining was found of a dark brown colour; a part of it readily dissolved in cold water, and the solution acted on gelatine.

The residual fluid of the portions of the infusion which had been acted on by the carbonates of soda and of ammonia, as in the instance of the carbonate of potash, gave no precipitate with gelatine, till they were saturated with an acid, so that, in all these cases, the changes are strictly analogous.

The infusion of galls, as appears from the analysis, contains in its primitive state calcareous matter. By the action of the mild alkalies, this substance is precipitated in union with a portion of the vegetable matter, in the form of an insoluble compound. The alkalies themselves, at the same time, enter into actual combination with the remaining tannin and gallic acid; and a part of the compound formed is precipitated, whilst another part remains in solution.

When the artificial carbonates of lime, magnesia, and barytes were separately boiled with portions of the infusion of galls for some hours, they combined with the tannin contained in it, so as to form with it insoluble compounds; and in each case, a deep green fluid was obtained, which gave no precipitate to gelatine, even when an acid was added, but which produced a deep black colour in the solutions of the salts of iron.

Sulphate of lime when finely divided, whether natural or artificial, after having been long heated with a small quantity of the infusion, was found to have combined with the tannin of it, and to have gained a faint tinge of light brown. The liquid became of a blue-green colour, and acted upon the salts of iron, but not upon gelatine; and there is every reason to suppose that it held in solution a triple compound, of gallic acid, sulphuric acid, and lime.

We owe to Mr. Proust the discovery that different solutions of the neutral salts precipitate the infusion of galls; and he supposes that the precipitation is owing to their combining with a portion of the water which held the vegetable matter in solution. In examining the solid matters thrown down from the infusion, by sulphate of alumine, nitrate of potash, acetite of potash, muriate of soda, and muriate of barytes, I found them soluble to a certain extent in water, and possessed of the power of acting upon gelatine. From the products given by their incineration, and by their distillation, I am, however, inclined to believe that they contain, besides tannin, a portion of gallic acid and extractive matter, and a quantity of the salt employed in the primitive solution.

It is well known that many of the metallic solutions occasion dense precipitates in the infusion of galls; and it has been generally supposed that these precipitates are composed of tannin and extractive matter, or of those two substances and gallic acid united to the metallic oxyde; but from the observation of different processes of this kind, in which the salts of iron and of tin were employed, I am inclined to believe that they contain also a portion of the acid of the saline compound.

When the muriate of tin was made to act upon a portion of the infusion, till no more precipitation could be produced in it, the fluid that passed through the filter still acted upon gelatine, and seemed to contain no excess of acid, for it gave a precipitate to carbonate of potash, without producing effervescence. The solid compound when decomposed by sulphuretted hydrogen, after the manner recommended by Mr. Proust was found strongly to redden litmus paper, and it copiously precipitated nitrate of silver; whereas the primitive infusion only rendered it slightly turbid; so that there is every reason to believe that the precipitate contained muriatic acid.

By passing the black and turbid fluid, procured by the action of solution of oxygenated sulphate of iron in excess upon a portion of the infusion, through finely-divided pure flint, contained in four folds of filtrating paper, I obtained a light olive green fluid, in which there was no excess of sulphuric acid, and which I am inclined to suppose was a solution of the compound of gallic acid and sulphate of iron, with superabundance of metallic salt. I have already mentioned that gallic acid when in very small proportion, does not precipitate the oxygenated salts of iron; and Mr. Proust in his ingenious paper upon the difference of the salts of iron, has supposed that, in the formation of ink, a portion of the oxyde of iron in union with gallic acid is dissolved by the sulphuric acid of the sulphate. This comes near to the opinion that they form a triple compound; and in reasoning upon the general phænomena, it seems fair to conclude that in the case of the precipitation of tannin by the salts of tin and iron, compounds are formed of tannin and the salts; and that of these compounds such as contain tin, are slightly soluble in water, whilst those that contain iron are almost wholly insoluble.

In examining the action of animal substances upon the infusion of galls with the view of ascertaining the composition of the compounds of gelatine, and of skin with tannin, I found that a saturated solution of gelatine, which contained the soluble matter of 50 grains of dry isinglass, produced from the infusion a precipitate that weighed nearly 91 grains; and in another instance, a solution containing 30 grains of isinglass gave about 56 grains; so that taking the mean of the two experiments, and allowing for the small quantity of insoluble matter in isinglass, we may conclude that 100 grains of the compound of gelatine and tannin formed by precipitation from saturated solutions, contain about 54 grains of gelatine, and 46 of tannin.

A piece of dry calf-skin, perfectly free from extraneous matter, that weighed 180 grains after being prepared for tanning by long immersion in water, was tanned in a portion of the infusion, being exposed to it for three weeks. When dry the leather weighed 295 grains; so that considering this experiment as accurate, leather quickly tanned by means of an infusion of galls, consists of about 61 grains of skin, and 39 of vegetable matter in 100 grains.

After depriving a portion of the infusion of all its tanning matter, by repeatedly exposing it to the action of pieces of skin, I found that it gave a much slighter colour to oxygenated sulphate of iron, than an equal portion of a similar infusion which had been immediately precipitated by means of isinglass; but I am inclined to attribute this effect, not to any absorption of gallic acid by the skin, but rather to the decomposition of it by the long-continued action of the atmosphere; for much insoluble matter had been precipitated during the process of tanning, and the residuum contained a small portion of acetous acid.

In ascertaining the quantity of tannin in galls, I found that 500 grains of good Aleppo galls gave by lixiviation with pure water till their soluble parts were taken up, and subsequent slow evaporation, 185 grains of solid matter. And this matter examined by analysis, appeared to consist

Of tannin	130 grains.
Of mucilage and matter rendered insoluble by evaporation . . .	12
Of gallic acid with a little extractive matter	31
Remainder, calcareous earth, and saline matter	12

The fluid obtained by the last lixiviation of galls, as

M. Deyeux observed, is pale green; and I am inclined to believe that it is chiefly a weak solution of gallate of lime. The ashes of galls, deprived of soluble matter furnish a very considerable quantity of calcareous earth. And the property which M. Deyeux discovered in the liquor of the last lixiviations of becoming red by the action of acids and of regaining the green colour by means of alkalies, I have observed more or less, in all the soluble compounds containing gallic acid and the alkaline earths.

3. *Experiments and Observations on Catechu or Terra Japonica.*

The extract called catechu is said to be obtained from the wood of a species of the mimosa,* which is found abundantly in India, by decoction and subsequent evaporation.

There are two kinds of this extract; one is sent from Bombay, the other from Bengal; and they differ from each other more in their external appearance than in their chemical composition. The extract from Bombay is of an uniform texture, and of a red-brown tint; its specific gravity being generally about 1·39. The extract from Bengal is more pliable, and less consistent; its colour is like that of chocolate externally, but when broken, its fracture presents streaks of chocolate and of red-brown. Its specific gravity is about 1·28. Their tastes are precisely similar, being astringent, but leaving in the mouth a sensation of sweetness. They do not deliquesce, or apparently change by exposure to the air.

The discovery of the tanning powers of catechu, is owing to the President of the Royal Society, who, concluding from its sensible properties that it contained tannin, furnished me in December, 1801, with a quantity for chemical examination.

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* See Kerr's Medical Observations, vol. v. p. 155.

In my first experiments, I found that the solutions of catechu copiously precipitated gelatine, and speedily tanned skin, and in consequence I began a particular investigation of their properties.

The strongest infusions and decoctions of the two different kinds of catechu do not sensibly differ in their nature, or in their composition. Their colour is deep red-brown, and they communicate this tinge to paper; they slightly redden litmus paper; their taste is highly astringent, and they have no perceptible smell.

The strongest infusions that I could obtain from the two kinds of catechu at 48° Fahrenheit were of the same specific gravity, 1·057. But by long decoction, I procured solutions of 1·102, which gave by evaporation, more than $\frac{1}{6}$ of their weight of solid matter.

Five hundred grains of the strongest infusion of catechu from Bombay furnished only 41 grains of solid matter; which from analysis appeared to consist of 34 grains of tannin or matter precipitable by gelatine, and 7 grains that were chiefly a peculiar extractive matter, the properties of which will be hereafter described. The quantity of solid matter given by the strongest infusion of the Bengal catechu, was the same, and there was no sensible difference in its composition. Portions of these solid matters, when incinerated, left a residuum which seemed to be calcareous; but it was too small in quantity to be accurately examined, and it could not have amounted to more than $\frac{1}{200}$ of their original weights.

The strongest infusions of catechu acted upon the acids and pure alkalies in a manner analogous to the infusion of galls. With the concentrated sulphuric and muriatic acids, they gave dense light fawn-coloured precipitates. With strong nitrous acid they effervesced; and lost their power of precipitating the solutions of isinglass, and the salts of iron. The pure alkalies entered into union with their tannin, so as to prevent it from being acted upon by gelatine.

When the solutions of lime, of strontia, or of barytes, were poured into the infusions, copious precipitates, of a shade of light brown, were formed; and the residual fluid assumed a paler tint of red, and was found to have lost its power of precipitating gelatine.

After lime had been boiled for some time with a portion of the infusion, it assumed a dull red colour. The liquor that passed from it through the filter had only a faint tint of red, did not act upon gelatine, and seemed to contain only a very small portion of vegetable matter. Pure magnesia, when heated with the infusion, acted upon it in an analogous manner; the magnesia became light red, and the residual fluid had only a very slight tinge of that colour. With carbonate of magnesia, the infusion became deeper in colour, and lost its power of precipitating gelatine; though it still gave, with oxygenated sulphate of iron, a light olive precipitate.

The carbonates of potash, of soda, and of ammonia, in their concentrated solutions, produced only a slight degree of turbidness in the infusions of catechu: they communicated to them a darker colour, and deprived them of the power of acting upon gelatine; though this power was restored by the addition of an acid.

After the mixture of the solution of carbonate of potash, and the infusions had been exposed to the atmosphere for some hours, a brown crust was found to have formed upon its surface, and a slight precipitation had taken place.

The salts of alumine precipitated the infusions, but less copiously than they precipitate the infusion of galls. A similar effect was produced by nitrate of potash, sulphate of magnesia, prussiate of potash, and many other neutral salts.

The nitrate, or acetite, of lead, in concentrated solution, when poured into the infusion, produced in it a dense light brown precipitate, which gave to the fluid a gelatinous appearance. After this effect, there was no free acid found in it; and both the tannin and the extractive matter seemed to have been carried down, in union with a portion of the metallic salt.

The solution of muriate of tin acted upon the infusion of catechu in a manner similar to that in which it acts upon the infusion of galls.

The least oxygenated sulphate of iron produced no change in the infusion. With the most oxygenated sulphate it gave a dense black precipitate, which, when diffused upon paper, appeared rather more inclined to olive than the precipitate from galls.

The infusions were precipitated by the solution of albumen.

The precipitates by gelatine had all a pale tint of red-brown, which became deeper when they were exposed to the air. The compound of gelatine and the tannin of the strongest infusions of catechu appeared, by estimation of the quantity of isinglass in the solutions used for their precipitation, to consist of about 41 parts of tannin, and 59 of gelatine.

Of two pieces of calf-skin which weighed, when dry, 132 grains each, and which had been prepared for tanning, one was immersed in a large quantity of the infusion of catechu from Bengal, and the other in an equal portion of the infusion of that from Bombay. In less than a month they were found converted into leather. When freed from moisture, by long exposure in the sunshine, they were weighed. The first piece had gained about 34 grains, and the second piece 35½ grains. The leather was of a much deeper colour than that tanned with galls, and on the upper surface was red-brown. It was not acted upon by hot or cold water; and its apparent strength was the same as that of similar leather tanned in the usual manner.

On examining the remainder of the infusions of catechu, in which skin had been converted into leather, I found in them much less extractive matter than I had reason to expect, from the comparative analysis of equal portions of the unaltered infusions made by solutions of gelatine. At first I was inclined to suppose that the deficiency arose from the action of the atmosphere upon the extractive matter, by which a part of it was rendered insoluble. But, on considering that there had been very little precipitation in the process, I was led to adopt the supposition, that it had entered into union with the skin, at the same time with the tannin; and this supposition was confirmed by new experiments.

Both kinds of catechu are almost wholly soluble in large quantities of water; and, to form a complete solution, about 18 ounces of water at 52°, are required to 100 grains of extract. The residuum seldom amounts to $\frac{1}{14}$ of the original weight of the catechu; and, in most cases, it is found to consist chiefly of calcareous and aluminous earths, and of fine sand, which, by accident or design, had probably been mixed with the primitive infusion at the time of its evaporation.

A considerable portion of both kinds of catechu is soluble in alcohol; but, after the action of alcohol upon it, a substance remains, of a gelatinous appearance and a light brown colour, which is soluble in water, and is analagous in its properties to gum or mucilage.

The peculiar extractive matter in the catechu, is much less soluble in water than the tanning principle; and, when a small quantity of water is used to a large quantity of catechu, the quantity of tannin taken up, as appears from the nature of the strongest infusion, is very much greater than that of the extractive matter. The extractive matter is much more soluble in warm water than in cold water; and, when saturated solutions of catechu are made in boiling water, a considerable quantity of extractive matter, in its pure state, falls down, as the liquor becomes cool.

The peculiar extractive matter of the catechu may be likewise obtained by repeatedly lixiviating the catechu, when in fine powder, till the fluids obtained cease to precipitate gelatine; the residual solid will then be found to be the substance in question.

The pure extractive matter, whether procured from the Bombay or Bengal catechu, is pale, with a faint tinge of red-brown. It has no perceptible smell; its taste is slightly astringent; but it leaves in the mouth, for some time, a sensation of sweetness stronger than that given by the catechu itself.

Its solution in water is at first yellow-brown; but it gains a tint of red by exposure to the air. Its solution in alcohol does not materially change colour in the atmosphere, and it is of an uniform dull brown.

The extractive matter, whether solid or in solution, was not found to produce any change of colour upon vegetable blues.

It became of a brighter colour by the action of the alkalies; but it was not precipitated from its solution in water by these bodies, nor by the alkaline earths.

The aqueous solutions of it, when mixed with solutions of nitrate of alumine and of muriate of tin, became slightly turbid.

To nitrate of lead it gave a dense light brown precipitate.

It was not perceptibly acted on by solution of gelatine; but, when solution of sulphate of alumine was added to the mixture of the two fluids, a considerable quantity of solid matter, of a light brown colour, was immediately deposited.

To the solution of oxygenated sulphate of iron, it communicated a fine grass-green tint; and a green precipitate was deposited, which became black by exposure to the air. It was not precipitated by the mineral acids.

Linen, by being boiled in the strongest solution of the extractive matter, acquired a light red-brown tint. The liquor became almost colourless, and after this produced very little change in the solution of oxygenated sulphate of iron.

Raw skin, prepared for tanning by being immersed in the strong solution, soon acquired the same kind of tint as the linen. It united itself to a part of the extractive matter; but it was not rendered by it insoluble in boiling water.

The solid extractive matter, when exposed to heat, softened and became darker in its colour, but did not enter into fusion. At a temperature below that of ignition it was decompounded. The volatile products of its decomposition were, carbonic acid, hydro-carbonate, and water holding in solution acetous acid and a little unaltered extractive matter. There remained a light and very porous charcoal.

In considering the manner in which the catechu is prepared, it would be reasonable to conclude that different specimens of that substance must differ in some measure in their composition, even in their pure states; and for the purposes of commerce, they are often adulterated to a considerable extent with sand and earthy matter. *

In attempting to estimate the composition of the purest catechu, I selected pieces from different specimens, with which I was supplied by the President, and reduced them together into powder; mixing, however, only those pieces which were from catechu of the same kind.

Two hundred grains of the powder procured in this way, from the catechu of Bombay, afforded by analysis:—

	Grains.
Tannin	109
Peculiar extractive matter . . .	68
Mucilage	13
Residual matter, chiefly sand and calcareous earth	10

The powder of the Bengal catechu gave, by similar methods of analysis, in 200 grains:—

Tannin	97
Peculiar extractive matter . . .	73
Mucilage	16

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* One specimen that I examined of the terra japonica of commerce, furnished by incineration, one-fifth of sand and earthy matter; and another specimen, nearly one-sixth.

Residual matter; sand, with a small quantity of calcareous and aluminous earths	14

In examining those parts of the catechu from Bengal, which were differently coloured, I found the largest proportion of tannin in the darkest part of the substance, and most extractive matter in the lightest part. It is probable that the inequality of composition in this catechu is owing to its being evaporated and formed without much agitation; in consequence of which, the constituent parts of it that are least soluble, being first precipitated, appear in some measure distinct from the more soluble parts, which assume the solid form at a later period of the process.

From the observations of Mr. Kerr,* it would appear that the pale catechu is the most sought after in India, and it is evidently that which contains most extractive matter. The extractive matter seems to be the substance that gives to the catechu the peculiar sweetness of taste which renders it so agreeable to the Hindoos, for the purpose of chewing with the betle-nut.

4. *Experiments and Observations on the astringent infusions of barks, and other vegetable productions.*

The barks that I examined were furnished me by my friend, Samuel Purkis, Esq. of Brentford; they had been collected in the proper season, and preserved with care.

In making the infusions, I employed the barks in coarse powder; and, to expedite the solution, a heat of 100° to 120° Fahrenheit was applied.

The strongest infusions of the barks of the oak, of the

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* Medical Observations, vol. v. p. 155.

Leicester willow, and of the Spanish chestnut, were nearly of the same specific gravity, 1·05. Their tastes were alike, and strongly astringent; they all reddened litmus paper; the infusion of the Spanish chestnut bark producing the highest tint, and that of the Leicester willow bark the feeblest tint.

Two hundred grains of each of the infusions were submitted to evaporation; and in this process the infusion of the oak bark furnished seventeen grains of solid matter; that of the Leicester willow about sixteen and a half grains; and that of the Spanish chestnut nearly an equal quantity.

The tannin given by these solid matters was, in that from the oak bark infusion, fourteen grains; in that from the willow bark infusion fourteen and a half grains; and in that from the Spanish chestnut bark infusion thirteen grains.

The residual substances of the infusions of the Spanish chestnut bark, and of the oak bark, slightly reddened litmus paper, and precipitated the solutions of tin of a fawn colour, and those of iron black. The residual matter of the infusion of the willow bark did not perceptibly change the colour of litmus; but it precipitated the salts of iron of an olive colour, and rendered turbid the solution of nitrate of alumine.

The solid matters produced by the evaporation of the infusions, gave, by incineration, only a very small quantity of ashes, which could not have been more than $\frac{1}{150}$ of their original weights. These ashes chiefly consisted of calcareous earth and alkali; and the quantity was greatest from the infusion of chestnut bark.

The infusions were acted on by the acids and the pure alkalies in a manner very similar to the infusion of galls. With the solutions of carbonated alkalies they gave dense fawn-coloured precipitates. They were copiously precipitated by the solutions of lime, of strontia, and of barytes; and by lime-water in excess, the infusions of oak and of chestnut bark seemed to be deprived of the whole of the vegetable matter they held in solution.

By being boiled for some time with alumine, lime, and magnesia, they became almost colourless, and lost their power of acting upon gelatine and the salts of iron. After being heated with carbonate of lime and carbonate of magnesia, they were found deeper coloured than before; and though they had lost their power of acting on gelatine, they still gave dense olive-coloured precipitates with the salts of iron.

In all these cases the earths gained tints of brown more or less intense.

When the compound of the astringent principles of the infusion of oak bark with lime, procured by means of lime-water, was acted on by sulphuric acid, a solution was obtained, which precipitated gelatine, and contained a portion of the vegetable principles, and a certain quantity of sulphate of lime; a solid fawn-coloured matter was likewise formed, which appeared to be sulphate of lime united to a little tannin and extractive matter.*

The solutions were copiously precipitated by solution of albumen.

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* M. Merat Guillot proposes a method of procuring pure tannin, (Annales de Chimie, tom. xli. p. 325,) which consists in precipitating a solution of tan by lime-water, and decomposing it by nitric or muriatic acid. The solution of the solid matter obtained in this way in alcohol, he considers as a solution of pure tannin; but from the experiments above-mentioned, it appears that it must contain, besides tannin, some of the extractive matter of the bark; and it *may* likewise contain saline matter.

The precipitates they gave with gelatine were similar in their appearance; their colour at first was a light tinge of brown, but they became very dark by exposure to the air. Their composition was very nearly similar; and, judging from the experiments on the quantity of gelatine employed in forming them, the compound of tannin and gelatine from the strongest infusion of oak bark, seems to consist, in the 100 parts, of 59 parts of gelatine, and 41 of tannin; that from the infusion of Leicester willow bark, of 57 parts of gelatine and 43 of tannin; and that from the infusion of Spanish chestnut bark, of 61 parts of gelatine, and 39 of tannin.

Two pieces of calf-skin, which weighed when dry 120 grains each, were tanned; one in the strongest infusion of Leicester willow bark, and the other in the strongest infusion of oak bark. The process was completed, in both instances, in less than a fortnight; when the weight of the leather formed by the tannin of the Leicester willow bark was found equal to 161 grains; and that of the leather formed by the infusion of oak bark was equal to 164 grains.

When pieces of skin were suffered to remain in small quantities of the infusions of the oak bark, and of the Leicester willow bark, till they were exhausted of their tanning principle, it was found, that though the residual liquors gave olive-coloured precipitates with the solutions of sulphate of iron, yet they were scarcely rendered turbid by solutions of muriate of tin; and there is every reason to suppose that a portion of their extractive matter had been taken up with the tannin by the skin.

I attempted, in different modes, to obtain uncombined gallic acid from the solid matter produced by the evaporation of the barks, but without success. When portions of this solid matter were exposed to the degree of heat that is required for the production of gallic acid from the Aleppo galls, no crystals were formed; and the fluid that came over gave only a brown colour to the solution of salts of iron, and was found to contain much acetous acid and empyreumatic oil.

When pure water was made to act, in successive portions, upon oak bark in coarse powder, till all its soluble parts were taken up, the quantities of liquor last obtained, though they did not act much upon solution of gelatine, or perceptibly redden litmus paper, produced a dense black with the solution of sulphate of iron: by evaporation, they furnished a brown matter, of which a part was rendered insoluble in water by the action of the atmosphere; and the part soluble in water was not in any degree taken up by sulphuric ether; so that, if it contained gallic acid, it was in a state of intimate union with extractive matter.

Two pieces of calf-skin, which weighed, when dry, ninety-four grains each, were slowly tanned; one, by being exposed to a weak infusion of Leicester willow bark, and the other, by being acted upon by a weak infusion of oak bark. The process was completed in about three months; and it was found, that one piece of skin had gained in weight fourteen grains, and the other piece about sixteen and a half grains. This increase is proportionally much less than that which took place in the experiment on the process of quick tanning. The colour of the pieces of leather was deeper than that of the pieces which had been quickly tanned; and, to judge from the properties of the residual liquors, more of the extractive matters of the barks had been combined with them.

The experiments of Mr. Biggin* have shown, that similar barks, when taken from trees at different seasons, differ as to the quantities of tannin they contain: and I have observed, that the proportions of the astringent principles in barks vary considerably, according as their age and size are different; besides, these proportions are often influenced by accidental circumstances, so that it is extremely difficult to ascertain their distinct relations to each other.

In every astringent bark, the interior white bark (that is, the part next to the alburnum) contains the largest quantity of tannin. The proportion of extractive matter is generally greatest in the middle or coloured part: but the epidermis seldom furnishes either tannin or extractive matter.

The white cortical layers are comparatively most abundant in young trees; and hence their barks contain, in the same weight, a larger proportion of tannin than the barks of old trees. In barks of the same kind, but of different ages, which have been cut at the same season, the similar parts contain always very nearly the same quantities of astringent principles; and the interior layers afford about equal portions of tannin.

An ounce of the white cortical layers of old oak bark, furnished, by lixiviation and subsequent evaporation, 108 grains of solid matter; and, of this, seventy-two grains were tannin. An equal quantity of the white cortical layers of young oak produced 111 grains of solid matter, of which seventy-seven were precipitated by gelatine.

An ounce of the interior part of the bark of Spanish chestnut, gave eighty-nine grains of solid matter, containing sixty-three grains of tannin.

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* Phil. Trans. for 1799, p. 299.

The same quantity of the same part of the bark of the Leicester willow, produced 117 grains, of which seventy-nine were tannin.

An ounce of the coloured or external cortical layers from the oak, produced forty-three grains of solid matter, of which nineteen were tannin.

From the Spanish chestnut forty-one grains, of which fourteen were tannin.

And from the Leicester willow, thirty-four grains, of which sixteen were tannin.

In attempting to ascertain the relative quantities of tannin in the different *entire* barks, I selected those specimens which appeared similar with regard to the proportions of the external and internal layers, and which were about the average thickness of the barks commonly used in tanning, namely, half an inch.

Of these barks, the oak produced, in the quantity of an ounce, sixty-one grains of matter dissolved by water, of which twenty-nine grains were tannin.

The Spanish chestnut, fifty-three grains, of which twenty-one were tannin.

And the Leicester willow, seventy-one grains, of which thirty-three were tannin.

The proportions of these quantities in respect to the tanning principle, are not very different from those estimated in Mr. Biggin's table.* The residual substances obtained in the different experiments differed considerably in their properties; but certain portions of them were, in all instances, rendered insoluble during the process of evaporation. The residuum of the chestnut bark, as in the instance of the strongest infusion, possessed slightly acid properties, but more than three-quarters of its weight consisted of extractive matter. All the residuums in solution, as in the other cases, were precipitated by muriate of tin; and after this precipitation the clear fluids acted much more feebly than before on the salts of iron; so that there is great reason for believing that the power of astringent infusions to precipitate the salts of iron, black or dark-coloured, depend partly upon the agency of the extractive matters they contain, as well as upon that of the tanning principle and gallic acid.

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* Phil. Trans. for 1799, p. 263.

In pursuing the experiments upon the different astringent infusions, I examined the infusions of the bark of the elm and of the common willow. These infusions were acted on by reagents, in a manner exactly similar to the infusions of the other barks; they were precipitated by the acids, by solutions of the alkaline earths, and of the carbonated alkalies; and they formed with the caustic alkalies, fluids not precipitable by gelatine.

An ounce of the bark of the elm furnished thirteen grains of tannin.

The same quantity of the bark of the common willow gave eleven grains.

The residual matter of the bark of the elm contained a considerable quantity of mucilage; and that of the bark of the willow, a small quantity of bitter principle.

The strongest infusions of the sumachs from Sicily and Malaga, agree with the infusions of barks, in most of their properties; but they differ from all the other astringent infusions that have been mentioned, in one respect; they give dense precipitates with the caustic alkalies. Mr. Proust has shewn that sumach contains abundance of sulphate of lime; and it is probably to this substance that the peculiar effect is owing.

From an ounce of Sicilian sumach, I obtained 165 grains of matter soluble in water, and of this matter seventy-eight grains were tannin.

An ounce of Malaga sumach produced 156 grains of soluble matter, of which seventy-nine appeared to be tannin.

The infusion of Myrobalans,* from the East Indies, differed from the other astringent infusions chiefly by the circumstance that it effervesced with the carbonated alkalies; and it gave with them a dense precipitate that was almost immediately redissolved. After the tannin had been precipitated from it by gelatine, it strongly reddened litmus paper, and gave a bright black with the solutions of iron. I expected to be able to procure gallic acid, by distillation, from the Myrobalans; but in this I was mistaken; they furnished only a pale yellow fluid, which gave merely a slight olive tinge to solution of sulphate of iron.

Skin was speedily tanned in the infusion of the Myrobalans; and the appearance of the leather was similar to the appearance of that from galls.

The strongest infusions of the teas are very similar in their agencies upon chemical tests, to the infusions of catechu.

An ounce of Souchong tea produced 48 grains of tannin.

The same quantity of green tea gave 41 grains.

Dr. Maton has observed, that very little tannin is found in cinchona, or in the other barks supposed to be possessed of fibrifuge properties. My experiments tend to confirm the observation. None of the infusions of the strongly bitter vegetable substances that I have examined, gave any precipitate to gelatine. And the infusions of quassia, of gentian, of hops, and of camomile, are scarcely affected by muriate of tin; so that they likewise contain very little extractive matter.

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* The Myrobalans used in these experiments are the fruit of the Terminalia Chebula.—Retz. Obs. Bot. Fasc. v. p. 31.

In all substances possessed of the astringent taste, there is great reason to suspect the presence of tannin: it even exists in substances which contain sugar and vegetable acids. I have found it in abundance in the juice of sloes; and my friend Mr. Poole, of Stowey, has detected it in port wine.

5. *General Observations.*

Mr. Proust has supposed in his paper upon tannin and its species,* that there exist different species of the tanning principle, possessed of different properties, and different powers of acting upon reagents, but all precipitable by gelatine. This opinion is sufficiently conformable to the facts generally known concerning the nature of the substances which are produced in organised matter; but it cannot be considered as proved, till the tannin in different vegetables has been examined in its pure or insulated state. In all the vegetable infusions which have been subjected to experiment, it exists in a state of union with other principles; and its properties must necessarily be modified by the peculiar circumstances of its combination.

From the experiments that have been detailed, it appears, that the *specific* agencies of tannin in all the different astringent infusions are the same. In every instance, it is capable of entering into union with the acids, alkalies, and earths; and of forming insoluble compounds with gelatine and with skin. The infusions of the barks affect the greater number of reagents in a manner similar to the infusion of galls; and, that this last fluid is rendered green by the carbonated alkalies, evidently depends upon the large proportion of gallic acid it contains. The infusion of sumach owes its characteristic property, of being precipitated by the caustic alkalies, to the presence of sulphate of lime; and, that the solutions of catechu do not copiously precipitate the carbonated alkalies, appears to depend upon their containing tannin in a peculiar state of union with extractive matter, and uncombined with gallic acid or earthy salts.

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* Annales de Chimie, tom. xli. p. 332.

In making some experiments upon the affinities of the tanning principle, I found that all the earths were capable of attracting it from the alkalies; and, so great is their tendency to combine with it, that by means of them, the compound of tannin and gelatine may be decomposed without much difficulty; for, after pure magnesia had been boiled for a few hours with this substance diffused through water, it became of a red-brown colour, and the fluid obtained by filtration produced a distinct precipitate with solution of galls. The acids have less affinity for tannin than for gelatine; and, in cases where compounds of the acids and tannin are acted on by solution of gelatine, an equilibrium of affinity is established, in consequence of which, by far the greatest quantity of tannin is carried down in the insoluble combination. The different neutral salts have, comparatively, feeble power of attraction for the tanning principle; but, that the precipitation which they occasion in astringent solutions, is not simply owing to the circumstance of their uniting to a portion of the water which held the vegetable substances in solution, is evident from many facts, besides those which have been already stated. The solutions of alum, and of some other salts which are less soluble in water than tannin, produce, in many astringent infusions, precipitates as copious as the more soluble saline matters; and sulphate of lime, and other earthy neutral compounds, which are, comparatively speaking, insoluble in water, speedily deprive them of their tanning principle.

From the different facts that have been stated, it is evident that tannin may exist in a state of combination in different substances, in which its presence cannot be made evident by means of solution of gelatine; and, in this case, to detect its existence, it is necessary to have recourse to the action of the diluted acids.

In considering the relations of the different facts that have been detailed, to the processes of tanning and of leather-making, it will appear sufficiently evident, that when skin is tanned in astringent infusions that contain, as well as tannin, extractive matter, portions of these matters enter, with the tannin, into chemical combination with the skin. In no case is there any reason to believe that gallic acid is absorbed in this process; and M. Seguin's ingenious theory of the agency of this substance, in producing the deoxygenation of skin, seems supported by no proofs. Even in the formation of glue from skin, there is no evidence which ought to induce us to suppose that it loses a portion of oxygen; and the effect appears to be owing merely to the separation of the gelatine, from the small quantity of albumen with which it was combined in the organised form, by the solvent powers of water.

The different qualities of leather made with the same kind of skin, seem to depend very much upon the different quantities of extractive matter it contains. The leather obtained by means of infusion of galls, is generally found harder, and more liable to crack, than the leather obtained from the infusions of barks: and, in all cases, it contains a much larger proportion of tannin, and a smaller proportion of extractive matter.

When skin is very slowly tanned in weak solutions of the barks, or of catechu, it combines with a considerable proportion of extractive matter; and, in these cases, though the increase of weight of the skin is comparatively small, yet it is rendered perfectly insoluble in water; and is found soft, and at the same time strong.

The saturated astringent infusions of barks contain much less extractive matter, in proportion to their tannin, than the weak infusions; and, when skin is quickly tanned in them, common experience shows that it produces leather less durable than the leather slowly formed.

Besides, in the case of quick tanning by means of infusions of barks, a quantity of vegetable extractive matter is lost to the manufacturer, which might have been made to enter into the composition of his leather. These observations show, that there is some foundation for the vulgar opinion of workmen, concerning what is technically called the *feeding* of leather in the slow method of tanning; and, though the processes of the art may in some cases be protracted for an unnecessary length of time, yet, in general, they appear to have arrived, in consequence of repeated practical experiments, at a degree of perfection which cannot be very far extended by means of any elucidations of theory that have as yet been made known.

On the first view it appears singular that, in those cases of tanning where extractive matter forms a certain portion of the leather, the increase of weight is less than when the skin is combined with pure tannin; but the fact is easily accounted for, when we consider that the attraction of skin for tannin must be probably weakened by its union with extractive matter; and, whether we suppose that the tannin and extractive matter enter together into combination with the matter of skin, or unite with separate portions of it, still, in either case, the primary attraction of tannin for skin must be, to a certain extent, diminished.

In examining astringent vegetables in relation to their powers of tanning skin, it is necessary to take into account, not only the quantity they contain of the *substance* precipitable by gelatine, but likewise the quantity, and the nature, of the extractive matter; and, in cases of comparison, it is essential to employ infusions of the same degree of concentration.

It is evident, from the experiments detailed in the third section, that of all the astringent substances which have been as yet examined, catechu is that which contains the largest proportion of tannin: and, in supposing, according to the common estimation, that from four to five pounds of common oak bark are required to produce one pound of leather, it appears, from the various synthetical experiments, that about half a pound of catechu would answer the same purpose.*

Also, allowing for the difference in the composition of the different kinds of leather, it appears, from the general detail of facts, that one pound of catechu, for the common use of the tanner, would be nearly equal in value to 2¼ pounds of galls, to 7½ pounds of the bark of the Leicester willow, to 11 pounds of the bark of the Spanish chestnut, to 18 pounds of the bark of the elm, to 21 pounds of the bark of the common willow, and to 3 pounds of sumach.

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* This estimation agrees very well with the experiments lately made by Mr. Purkis, upon the tanning powers of Bombay catechu in the processes of manufacture, and which he has permitted me to mention. Mr. Purkis found, by the results of different accurate experiments, that one pound of catechu was equivalent to seven or eight of oak bark.

Various menstruums have been proposed for the purpose of expediting and improving the process of tanning, and amongst them, lime-water and the solutions of pearl-ash; but as these two substances form compounds of tannin which are not decomposable by gelatine, it follows that their effect must be highly pernicious; and there is very little reason to suppose that any bodies will be found which, at the same time that they increase the solubility of tannin in water, will not likewise diminish its attraction for skin.

OBSERVATIONS ON THE PROCESS OF TANNING.

1. *On the Preparation of Skin for Tanning.*[*]

In all the processes for forming leather, the skins are depilated, and freed from flesh and extraneous matter before they are submitted to the action of the tanning lixivium. In some cases, when large skins are employed, a slight degree of putrefaction is induced, for the purpose of enabling the hair to be readily separated; but in general this effect is produced by a mixture of lime and water.

The process by putrefaction is so simple as to require no comment: the epidermis is loosened by it, and the cellular substance that constitutes the bulb of the hair softened in such a manner that it may be easily separated from the cutis or true skin.

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[*] [From the Journals of the Royal Institution, 1803.]

When lime is employed, it has been generally supposed that it acts by destroying the epidermis, so as to render it soluble in water. This, however, does not appear to be the case: I exposed to two ounces of lime-water four grains of epidermis, separated from cow-skin, and which had been freed from loose moisture by blotting-paper; but after five days, it appeared rather of larger volume than before; and instead of having lost any weight, I found that it had gained very nearly half a grain.

The epidermis has been supposed to consist of coagulated albumen. In comparing its properties with those of the coagulated white of the egg, there was a striking analogy perceived between them: both were soluble in the caustic alkalies by long exposure, and were acted upon by the acids.

In examining the circumstance of the action of lime-water, and of milk of lime, upon skin, I have always observed that the cuticle is rendered extremely loose and friable after this action; from which it is probable that it combines with the lime, so as to form an insoluble compound. This may be observed indeed in washing the hands with lime-water: the cuticle becomes extremely rough and dry; whereas, after the action of weak alkaline solutions, which form soluble compounds with it, it is found smooth.

Not only the epidermis, but likewise the soft matter at the extremity of the hair, is acted upon by lime; and this effect must tend considerably to facilitate the process of depilation. Likewise the fat and oily matter adhering to the skin, form saponaceous compounds with the earth, and these compounds are removed with other extraneous matter, before the skins are submitted to any new chemical agents.

It has been proposed to use the residuum of the tanning lixivium, or the exhausted ooze, for the purpose of depilation; but this liquor seems to contain no substances capable of acting upon the epidermis, or of loosening the hair; and when skin is depilated by being exposed to it, the effect must really be owing to incipient putrefaction.

Skins, after being depilated and cleansed, are in this country generally subjected to other processes of preparation before they are impregnated with the tanning principle.

The large and thick hides which have undergone incipient putrefaction, are introduced for a short time into a strong infusion of bark, when they are said by the manufacturers to be *coloured;* and after this they are acted upon by water impregnated with a little sulphuric acid, or acetous acid formed by the fermentation of barley or rye. In this case they become harder and denser than before, and fitted, after being tanned, for the purpose of forming the stouter kinds of sole-leather. The acids are capable of combining both with skin and with tannin; and it would appear that, in this process, a triple combination must be effected on the surface of the skin, though from theory one should be disposed to conclude that the interior part could be little modified in consequence of the colouring, and the action of the acids.

The light skins of cows, the skins of calves, and all small skins, are treated in a very different way, being submitted for some days to the action of a lixivium, called the grainer, made by the infusion of pigeons' dung in water. After this operation, they are found thinner and softer than before, and more proper for producing flexible leather.

When the infusion of pigeons' dung is examined, after being freshly made, it is found to contain a little carbonate of ammonia; but in a short time it undergoes fermentation, when carbonic acid and hydro-carbonate are given out by it, and a small quantity of acetous acid formed. The alkali in the grainer may probably have some action upon the skin; it may be supposed to free it from any oils or calcareous soaps that remained adhering to it; but the great effect probably depends upon the complicated process of fermentation, during which the skin loses its elasticity, and becomes soft; and it is found by tanners, that dung which has undergone fermentation is wholly unfit for their use.

I have tried several experiments on different substances, as substitutes for the pigeons' dung used in the grainer, but without gaining successful results. Very weak solutions of carbonate of potash and carbonate of ammonia seemed to soften considerably small pieces of skin that had been depilated by lime; but when they were tried by Mr. Purkis, in the processes of manufacture, the effects were less distinct. In the western counties of England the excrement of dogs is employed instead of pigeons' dung, and culver or the dung of fowls is in common use. The dung of graminivorous quadrupeds enters only slowly into fermentation, and it is not found efficacious in the process.

2. *On the Impregnation of Skin with the Tanning Principle.*

The tanning lixivium or ooze is generally made in this country, by infusing bruised or coarsely powdered oak bark in water.

Skins are tanned by being successively immersed in lixiviums, saturated in different degrees with the astringent principles of the bark. The lixiviums first employed are usually weak; but for the completion of the process they are made as strong as possible.

In the process of tanning, the skin gains new chemical properties; it increases in weight, and becomes insoluble in boiling water.

The infusions of oak bark, when chemically examined, are found to contain two principal substances; one is precipitable by solution of gelatine, made from glue or isinglass; and gives a dense black with solution of common sulphate of iron. The other is not thrown down by solution of gelatine; but it precipitates the salts of iron of a brownish black, and the salts of tin of a fawn colour.

The substance precipitable by solution of gelatine is the tanning principle, or the tannin of Seguin. It is essential to the conversion of skin into leather, and in the process of tanning it enters into chemical union with the matter of skin, so as to form with it an insoluble compound. The other substance, the substance not precipitable by gelatine, is the colouring or extractive matter; it is capable of entering into union with skin, and it gives to it a brown colour; but it does not render it insoluble in boiling water.

It has been usually supposed that the infusion of oak bark contains a peculiar acid called gallic acid; but some late experiments render this opinion doubtful: and this principle, if it exists in oak bark, is in intimate combination with the extractive or colouring matter.

In the common process of tanning, the skin, which is chiefly composed of gelatine, slowly combines in its organised form with the tannin and extractive matter of the infusions of bark; the greater proportion of its increase of weight is, however, owing to tannin, and it is from this substance the leather derives its characteristic properties; but its colour, and the degree of its flexibility, appear to be influenced by the quantity of colouring matter that it contains.

When skin, in large quantity, is suffered to exert its full action upon a small portion of infusion of bark, containing tannin and extractive matter, the fluid is found colourless. It gives no precipitate to solution of glue, and produces very little effect upon the salts of iron or of tin.

The tanning principle of oak bark is more soluble in water than the extractive matter. And the relative proportion of tannin to extractive matter is much greater in strong infusions of oak bark, than in weak ones; and when strong infusions are used for tanning, a larger proportion of tannin is combined with the matter of skin.

For calf skins, and light cow-skins, which are usually prepared in the grainer, weak lixiviums are used in the first part of the process; but thick ox-hides, for the purpose of stout sole-leather, are generally kept in strong ooze, preserved constantly in a state approaching to saturation by means of strata of bark.

Calf skins, and light cow skins, in the usual process, require for their full impregnation with tannin from two to four months, but thick ox-hides demand from ten to eighteen months.

In any case the state of the skin with regard to impregnation with tannin may be easily judged of, if it be cut transversely with a sharp knife: in this case the tanned part appears of a nutmeg colour; but the unimpregnated skin retains its whiteness.

The tanned hides designed for sole-leather, are, while drying, generally smoothed with a stout steel pin, and beat with a mallet. By this process they are rendered denser, firmer, and less permeable to water. Calf-skins are not subjected to the operation of beating; and they are treated in different ways by the currier, according as they are needed for different purposes.

3. *General Remarks relating to the processes of Tanning.*

A very great number of vegetable productions, besides the oak bark, contain the principle essential to the conversion of skin into leather: galls, sumach, the bark of the Spanish chesnut, of the elm, of the common willow, and of the Leicester willow, the branches of the myrtle, tormentil, and heath, have all been used in the process of tanning.

Different methods have been proposed for estimating the quantity of tannin in different vegetable productions. Tannin by being dissolved in water, increases its specific gravity, and the hydrometer has been used for estimating the strength of the tanning ooze. The results given by this instrument are, however, often fallacious in comparative experiments, in consequence of the presence of extractive matter, and of saline substances; and the action of the solution of gelatine affords the best indication of the quantity of the tanning principle.

The solution of gelatine most proper for the general purposes of experiments, is made by dissolving an ounce of glue or of isinglass, in three pints of boiling water.

The substance to be examined as to its tanning power, may be used in the quantity of two ounces; it should be in a state of coarse powder, or in small fragments. A quart of boiling water will be sufficient to dissolve its astringent principles.

The solution of glue, or gelatine, must be poured into the astringent infusion, till the effect of the precipitation is at an end. The turbid liquor must then be passed through a piece of blotting-paper, which has been before weighed.

When the precipitate has been collected, and the paper dried, the increase of weight is determined, and about two-fifths of this increase of weight may be taken as the quantity of tannin in the ounce of the substance examined.

When solution of gelatine cannot be obtained, a solution of albumen may be used. It is made by agitating the white of an egg in a pint of cold water. It does not putrefy nearly so readily as the solution of glue, and it may be employed with equal advantage in experiments of comparison; but the composition of the precipitates it forms with tannin, has not as yet been ascertained.

The tanning principle in different vegetables is possessed of the same general characters; but it often exists in them in states of combination with other substances.

In galls it is in union with gallic acid. In sumach it is mixed with saline matter, particularly sulphate of lime; and in the greater number of barks it is in combination with mucilage and different extractive and colouring matters.

Leather tanned by means of different astringent infusions, differs considerably in composition; but it seldom contains more than one-third of its weight of vegetable matter.

Gallic acid, and saline matters in general, in cases when they are combined with tannin, are not absorbed with it by skin; but they remain in their primitive forms.

The leather made from infusions of Aleppo galls, and of sumach, is composed probably of pure tannin and the matter of skin. Its colour is very pale, and the increase of weight is greater than in most other cases.

Extractive, or colouring matters, in cases where they exist in astringent infusions, as in the instance of oak bark already mentioned, are wholly or partly absorbed with the tannin by the skin. The leather from barks in general is coloured, and contains different proportions of extractive matter. Of all the substances that have been examined as to their tanning properties, catechu or terra japonica, is that which is richest in the tanning principle. This substance is the extract of the wood of a species of the mimosa, which grows abundantly in India; and calculating on its price, and on the quantities in which it may be procured, there is great reason to believe that it may be made a valuable article of commerce.

In a paper published in the Philosophical Transactions for 1803, a statement is given of the comparative value of different astringent substances, oak bark being considered a standard.

The attraction of tannin for water is much stronger than that of any other of the principles usually found in astringent vegetables; and the saturated infusions obtained from substances containing very different proportions of astringent matters, are usually possessed of the same degree of strength with regard to the tanning powers.

When saturated solutions of the tanning principle are used in the process of manufacture, the leather is tanned in a much shorter time than in the common operation with weaker infusions. The rapid method of tanning has been recommended by Mr. Seguin; and is ably described in a pamphlet published by Mr. Desmond.

It has however been generally observed, that leather too quickly tanned is more rigid, and more liable to crack than leather slowly tanned. And there is every reason to believe that its texture must be less equable, as the exterior strata of skin would be perfectly combined with tannin before the interior strata were materially acted upon: and the want of colouring or extractive matter in the strongest lixivium, in many cases must affect the nature of the leather.

The substances used for tanning should, in all cases, be preserved in as dry a state as possible before they are used. When they are exposed to moisture and air, the tanning principle by degrees is destroyed in them, and for the most part converted into insoluble matter.

The process of drying bark by heat, when carefully conducted, must, as there is great reason to believe, on the whole be advantageous. The tanning principle is not destroyed at a temperature below 400°. And in fresh vegetable substances, tanning appears to be sometimes developed or formed by the long application of a low heat: this fact I observed with my friend Mr. Poole in September, 1802, with regard to acorns; and I have since made the same remark upon the horse-chesnut.

AN ACCOUNT OF SOME ANALYTICAL EXPERIMENTS ON A MINERAL PRODUCTION FROM DEVONSHIRE, CONSISTING PRINCIPALLY OF ALUMINE AND WATER.*

I. *Preliminary Observations.*

THIS fossil was found many years ago by Dr. Wavel, in a quarry near Barnstaple: Mr. Hatchett, who visited the place in 1796, described it as filling some of the cavities and veins in a rock of soft argillaceous schist. When first made known, it was considered as a zeolite; Mr. Hatchett, however, concluded from its geological position, that it most probably did not belong to that class of stones; and Dr. Babington, from its physical characters, and from some experiments on its solution in acid, made at his request by Mr. Stockler, ascertained that it was a mineral body, as yet not described, and that it contained a considerable proportion of aluminous earth.

It is to Dr. Babington that I am obliged for the opportunity of making a general investigation of its chemical nature; and that gentleman liberally supplied me with specimens for analysis.

II. *Sensible Characters of the Fossil.*

The most common appearance of the fossil is in small hemispherical groups of crystals, composed of a number of filaments radiating from a common centre, and inserted on the surface of the schist; but in some instances it exists as a collection of irregularly disposed prisms forming small veins in the stone: as yet I believe, no insulated or distinct crystal has been found. Its colour is white, in a few cases with a tinge of gray or of green, and in some pieces (apparently beginning to decompose) of yellow. Its lustre is silky; some of the specimens possess semi-transparency, but in general it is nearly opaque. Its texture is loose, but its small fragments possess great hardness, so as to scratch agate.

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* [From Phil. Trans. for 1805.]

It produces no effect on the smell when breathed upon, has no taste, does not become electrical or phosphorescent by heat or friction, and does not adhere to the tongue till after it has been strongly ignited. It does not decrepitate before the flame of the blow-pipe; but it loses its hardness, and becomes quite opaque. In consequence of the minuteness of the portions in which it is found, few of them exceeding the size of a pea, it is very difficult to ascertain its specific gravity with any precision; but from several trials I am disposed to believe, that it does not exceed 2·70, that of water being considered as 1·00.

III. *Chemical Characters of the Fossil.*

The perfectly white and semi-transparent specimens of the fossil are soluble both in the mineral acids and in fixed alkaline lixivia by heat, without sensibly effervescing and without leaving any notable residuum; but a small part remains undissolved, when coloured or opaque specimens are exposed to the alkaline lixivia.

A small semi-transparent piece, acted on by the highest heat of an excellent forge, had its crystalline texture destroyed, and was rendered opaque; but it did not enter into fusion. After the experiment it adhered strongly to the tongue, and was found to have lost more than a fourth of its weight. Water and alcohol, whether hot or cold, had no effect on the fossil. When it was acted on by a heat of from 212° to 600° Fahrenheit in a glass tube, it gave out an elastic vapour, which when condensed appeared as a clear fluid possessing a slight epyreumatic smell, but no taste different from that of pure water.

The solution of the fossil in sulphuric acid, when evaporated sufficiently, deposited crystals which appeared in thin plates, and had all the properties of sulphate of alumine; and the solid matter, when re-dissolved and mixed with a little carbonate of potash, slowly deposited octahedral crystals of alum. The solid matter precipitated from the solution of the white and semi-transparent fossil in muriatic acid, was in no manner acted upon by solution of carbonate of ammonia, and therefore it could not contain any glucine or ittria; and its perfect solubility without residuum in alkaline lixivia shewed that it was alumine.

When the opaque *varieties* of the fossil were fully exposed to the agency of alkaline lixivia, the residuum never amounted to more than one-twentieth part of the weight of the *whole*. In the white opaque variety, it was merely calcareous earth, for when dissolved in muriatic acid, not in excess, it gave a white precipitate when mixed with solution of oxalate of ammonia, and did not affect solution of prussiate of potash and iron.

In the green opaque variety, calcareous earth was indicated by solution of oxalate of ammonia; and it contained oxyde of manganese; for it was not precipitated by solution of ammonia; but was rendered turbid, and of a grey colour, by solution of prussiate of potash and iron.

The residuum of the alkaline solution of the yellow variety, when dissolved in muriatic acid, produced a small quantity of white solid matter when mixed with the solution of the oxalate of ammonia, and gave a light yellow precipitate by exposure to ammonia; but after this, when neutralized, it did not affect prussiate of potash and iron, so that its colouring matter, as there is every reason to believe, was *oxyde of iron.*

IV. *Analysis of the Fossil.*

Eighty grains of the fossil, consisting of the whitest and most transparent parts that could be obtained, were introduced into a small glass tube, having a bulb of sufficient capacity to receive them with great ease. To the end of this tube, a small glass globe attached to another tube, communicating with a pneumatic mercurial apparatus, was joined by fusion by means of the blowpipe.

The bulb of the tube was exposed to the heat of an argand-lamp; and the globe was preserved cool by being placed in a vessel of cold water. In consequence of this arrangement, the fluid disengaged by the heat, became condensed, and no elastic matter could be lost. The process was continued for half an hour, when the glass tube was quite red.

A very minute portion only of permanently elastic fluid passed into the pneumatic apparatus, and when examined, it proved to be common air. The quantity of clear fluid collected, when poured into another vessel, weighed 19 grains, but when the interior of the apparatus had been carefully wiped and dried, the whole loss indicated was 21 grains. The 19 grains of fluid had a faint smell, similar to that of burning peat; it was transparent, and tasted like distilled water; but it slightly reddened litmus paper. It produced no cloudiness in solutions of muriate of barytes, of acetate of lead, of nitrate of silver, or of sulphate of iron.

The 59 grains of solid matter were dissolved in diluted sulphuric acid, which left no residuum; and the solution was mixed with potash, in sufficient quantity to cause the alumine at first precipitated again to dissolve. What remained undissolved by potash, after being collected, and properly washed, was heated strongly and weighed; its quantity was a grain and a quarter. It was white, caustic to the taste, and had all the properties of lime.

The solution was mixed with nitric acid till it *became sour.* Solution of carbonate of ammonia was then poured into it till the effect of decomposition ceased. The whole thrown into a filtrating apparatus left solid matter, which when carefully washed and dried at the heat of ignition, weighed 56 grains. They were pure alumine: hence, the general results of the experiments, when calculated upon, indicated for 100 parts of this specimen,

Of alumine	70
Of lime	1·4
Of fluid	26·2
Loss	2·4

The loss I am inclined to attribute to some fluid remaining in the stone after the process of distillation; for I have found, from several experiments, that a red heat is not sufficient to expel all the matter capable of being volatilized, and that the full effect can only be produced by a strong white heat.

Fifty grains of a very transparent part of the fossil, by being exposed in a red heat for fifteen minutes, lost 13 grains; but when they were heated to whiteness, the deficiency amounted to 15 grains, and the case was similar in other trials.

Different specimens of the fossil were examined with great care, for the purpose of ascertaining whether any minute portion of fixed alkali existed in them; but no indications of this substance could be observed; the processes were conducted by means of solution of the unaltered fossil in nitric acid; the earths and oxydes were precipitated from the solution by being boiled with carbonate of ammonia; and after their separation, the fluid was evaporated to dryness, and the nitrate of ammonia decomposed by heat, when no residuum occurred.

A comparative analysis of 30 grains of a very pellucid specimen was made by solution in lixivium of potash. This specimen lost 8 grains by long continued ignition, after which it easily dissolved in the lixivium by heat, leaving a residuum of a quarter of a grain only, which was red oxyde of iron. The precipitate from the solution of potash, made by means of muriate of ammonia, weighed, when properly treated, 21 grains.

Several specimens were distilled in the manner above described, and in all cases the water collected had similar properties. The only test by which the presence of acid in it could be detected, was litmus paper; and in some cases the effect upon this substance was barely perceptible.

V. *General Observations.*

I have made several experiments with the hope of ascertaining the nature of the acid matter in the water; but from the impossibility of procuring any considerable quantity of the fossil, they have been wholly unsuccessful.

It is, however, evident from the experiments already detailed, that it is not one of the known mineral acids.

I am disposed to believe, from the minuteness of its proportion, and from the difference of this proportion in different cases, that it is not essential to the composition of the stone; and that, as well as the oxyde of manganese, that of iron, and the lime, it is only an accidental ingredient, and on this idea the pure matter of the fossil must be considered as a chemical combination *of about thirty parts of water, and seventy of alumine.*[*]

The experiment of M. Theodore de Saussure on the precipitation[†] of alumine from its solutions, have demonstrated the affinity of this body for water; but as yet I believe no aluminous stone, except that which I have just described, has been found, containing so large a proportion of water, as thirty parts in the hundred.

The diaspore which has been examined by M. Vauquelin, and which loses sixteen or seventeen parts in the hundred by ignition, and which contains nearly

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[*] [The following year, in a letter addressed to Mr. Nicholson from Killarney, in Ireland, of the 15th June, he mentions that he had ascertained that the acid referred to in the text was the fluoric "in such a peculiar state of combination as not to be rendered sensible by sulphuric acid."—Nicholson's Journal, vol. 14. p. 267.

Many years after this mineral was discovered by Fuchs to contain a large proportion of phosphoric acid. According to the analysis of Berzelius in 1809, it is composed—

Phosphoric acid	33·40
Fluoric acid	2·06
Alumine	35.35
Lime	0·50
Oxyde of iron and manganese	1.25
Water	26·80

Ann. de Chimie et Phys. tom. xii. p. 19.

He had no difficulty in detecting fluoric acid by the action of the sulphuric.]

[†] Journal de Physique, tom. lii. p. 280.

eighty of alumine, and only three of oxyde of iron, is supposed by that excellent chemist to be a compound of alumine and water. Its physical and chemical characters differ, however, very much from those of the new fossil, and other researches are wanting to ascertain whether the part of it volatilized by heat is of the same kind.

I have examined a fossil from near St. Austle, in Cornwall, very similar to the fossil from Barnstaple, in all *its general chemical characters;* and I have been informed, that an analysis of it, made by the Rev. William Gregor some months since, proves that it consists of similar ingredients.

Dr. Babington has proposed to call the fossil from Devonshire *Wavellite,* from Dr. Wavel, the gentleman who discovered it; but if a name founded upon its chemical composition be preferred, it may be denominated Hydrargillite; from ὑδωρ, water, and ἀργιλλος, clay.

ON A METHOD OF ANALYZING STONES CONTAINING FIXED ALKALI, BY MEANS OF THE BORACIC ACID.*

I HAVE found the boracic acid a very useful substance for bringing the constituent parts of stones containing a fixed alkali into solution. Its attraction for the different simple earths is considerable at the heat of ignition, but the compounds that it forms with them are easily decomposed by the mineral acids dissolved in water, and it is on this circumstance that the method of analysis is founded.

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* [From the Phil. Trans. for 1805. The Copley medal of this year was awarded to the author for the preceding papers published in the Philosophical Transactions.]

The processes are very simple.

100 grains of the stone to be examined in very fine powder, must be fused for about half an hour, at a strong red heat, in a crucible of platina or silver, with 200 grains of boracic acid.

An ounce and a half of nitric acid, diluted with seven or eight times its quantity of water must be digested upon the fused mass till the whole is decomposed.

The fluid must be evaporated till its quantity is reduced to an ounce and a half or two ounces. If the stone contain silex, this earth will be separated in the process of solution and evaporation, and it must be collected upon a filter, and washed with distilled water till the boracic acid and all the saline matter is separated from it.

The fluid, mixed with the water that has passed through the filter, must be evaporated, till it is reduced to a convenient quantity, such as that of half a pint; when it must be saturated with carbonate of ammonia, and boiled with an excess of this salt, till all the materials that it contains, capable of being precipitated, have fallen to the bottom of the vessel.

The solution must then be separated by the filter, and the earths and metallic oxydes retained.

It must be mixed with nitric acid till it tastes strongly sour, and evaporated till the boracic acid appears free.

The fluid must be passed through the filter, and subjected to evaporation till it becomes dry; when, by exposure to a heat equal to 450° Fahrenheit, the nitrate of ammonia will be decomposed, and the nitrate of potash or soda will remain in the vessel.

It will be unnecessary for me to describe minutely the method of obtaining the remaining earths and metallic oxydes free from each other, as I have used the common processes. I have separated the alumine by solution of potash, the lime by sulphuric acid, the oxyde of iron by succinate of ammonia, the manganese by hydrosulphuret of potash, and the magnesia by pure soda.

A DISCOURSE

INTRODUCTORY TO A COURSE OF LECTURES ON CHEMISTRY,

DELIVERED IN THE

THEATRE OF THE ROYAL INSTITUTION,

ON THE 21ST JANUARY, 1802.

A SYLLABUS OF THIS COURSE OF LECTURES.

OUTLINES OF A COURSE OF LECTURES

ON

CHEMICAL PHILOSOPHY.

[The introductory lecture which follows, and the syllabus of lectures of which it formed a part, with the outlines of a course of lectures on chemical philosophy, are selected for insertion in this portion of the Author's Works on account both of the time in which they appeared and their nature and object. In point of time, they belong to his early productions; and are as characteristic of his scientific youth, with its enthusiasm and vigor, as his essays were of his infancy in science.—Designed by him for an audience supposed to be ignorant of chemistry; and yet enlightened and refined, for the purpose of rousing attention, and exciting an interest, and giving elementary knowledge, they appear well adapted to answer the same purposes to readers of a similar class, and to introduce those who are not well instructed in chemistry to his other and less elementary writings, which will follow. To chemical readers it is hoped, they may not be unacceptable, as historical sketches of the then state of the science just on the eve of a great revolution, mainly owing to his labours.]

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ADVERTISEMENT.

I AM induced to publish the following discourse in consequence of the request of a part of the audience before whom it was delivered, the accuracy of whose judgment it would be presumptuous in me to question. It was not originally intended for the press. The subject is too important and sublime to be justly treated in an occasional composition; and the views I have taken were designed rather to excite feelings of interest concerning it, than to give minute information.

HUMPHRY DAVY.

26*th April*, 1802.

A DISCOURSE

INTRODUCTORY TO A

COURSE OF LECTURES ON CHEMISTRY.

Chemistry is that part of natural philosophy which relates to those intimate actions of bodies upon each other, by which their appearances are altered, and their individuality destroyed.

This science has for its objects all the substances found upon our globe. It relates not only to the minute alterations in the external world, which are daily coming under the cognizance of our senses, and which in consequence, are incapable of affecting the imagination, but likewise to the great changes, and convulsions in nature, which, occurring but seldom, excite our curiosity, or awaken our astonishment.

The phænomena of combustion, of the solution of different substances in water, of the agencies of fire; the production of rain, hail, and snow, and the conversion of dead matter into living matter by vegetable organs, all belong to chemistry; and, in their various and apparently capricious appearances, can be accurately explained only by an acquaintance with the fundamental and general chemical principles.

Chemistry, considered as a systematic arrangement of facts, is of later origin than most of the other sciences; yet certain of its processes and operations have been always more or less connected with them; and, lately, by furnishing new instruments and powers of investigation, it has greatly contributed to increase their perfection, and to extend their applications.

Mechanical philosophy, regarded as the science of the motions of the masses of matter, in its theories and practices, is, to a certain extent, dependent upon chemical laws. How in fact can the mechanic calculate with accuracy upon the powers of solids, fluids, or gases, in communicating motion to each other, unless he is previously acquainted with their particular chemical affinities, or propensities to remain disunited, or to combine? It is to chemistry that he is indebted for the knowledge of the nature and properties of the substances he employs; and he is obliged to that science for the artificial production of the most powerful and most useful of his agents.

Natural history and chemistry are attached to each other by very intimate ties. For while the first of these sciences treats of the general external properties of bodies, the last unfolds their internal constitution and ascertains their intimate nature. Natural history examines the beings and substances of the external world, chiefly in their permanent and unchanging forms; whereas chemistry by studying them in the laws of their alterations, developes and explains their active powers and the particular exertions of those powers.

It is only in consequence of chemical discoveries that that part of natural history which relates to mineral substances has assumed the form of a science. Mineralogy, at a period not very distant from the present, consisted merely of a collection of terms badly arranged, according to certain vague external properties of substances. It is now founded upon a beautiful and methodical classification; and that chiefly in consequence of the comparison of the intimate composition of the bodies it represents with their obvious forms and appearances. The mind of the mineralogist is no longer perplexed by endeavours to discover the loose and varying analogies between the colours, the shapes, and the weights of different substances. By means of the new method of analysis, he is furnished with instruments of investigation immediately applicable, and capable of producing uniform and accurate results.

Even botany and zoology as branches of natural history, though independent of chemistry as to their primary classification, yet are related to it so far as they treat of the constitution and functions of vegetables and animals. How dependent in fact upon chemical processes are the nourishment and growth of organized beings; their various alterations of form, their constant production of new substances, and finally their death and decomposition, in which nature seems to take unto herself those elements and constituent principles, which for a while she had lent to a superior agent as the organs and instruments of the spirit of life!

And in pursuing this view of the subject, medicine and physiology, those sciences which connect the preservation of the health of the human being with the abstruse philosophy of organized nature, will be found to have derived from chemistry most of their practical applications, and many of the analogies which have contributed to give to their scattered facts order and systematic arrangement. The art of preparing those substances which operate powerfully upon animal bodies, and which according to their different modes of exhibition are either efficient remedies or active poisons, is purely chemical. Indeed the want of an acquaintance with scientific principles in the processes of pharmacy has often been productive of dangerous consequences; and the study of the simple and unvarying agencies of dead matter ought surely to precede investigations concerning the mysterious and complicated powers of life. Knowing very little of the laws of his own existence, man has nevertheless derived some useful information from researches concerning the nature of respiration; and the composition and properties of animal organs even in their dead state. And if the connection of chemistry with physiology has given rise to some visionary and seductive theories; yet even this circumstance has been useful to the public mind in exciting it by doubt, and in leading it to new investigations. A reproach, to a certain degree just, has been thrown upon those doctrines known by the name of the chemical physiology; for in the applications of them, speculative philosophers have been guided rather by the analogies of words than of facts. Instead of slowly endeavouring to lift up the veil concealing the wonderful phænomena of living nature; full of ardent imaginations, they have vainly and presumptuously attempted to tear it asunder.

Though astronomy in its sublime views, and its mathematical principles, is far removed from chemistry, yet to this science it is indebted for many of its instruments of experiments. The progress of the astronomer has been in some measure commensurate with that of the chemical artist, who, indeed, by his perfection of the materials used for the astronomical apparatus, has afforded to the investigating philosopher the means of tracing the revolutions of the planets, and of penetrating into space, so as to discover the forms and appearances of the distant parts of the universe.

It would be unnecessary to pursue this subject to a greater extent. Fortunately for man, all the different parts of the human mind are possessed of certain harmonious relations; and it is even difficult to draw the line of distinction between the sciences; for as they have for their objects only dead and living nature, and as they consist of expressions of facts more or less analogous, they must all be possessed of certain ties of connection, and of certain dependencies on each other. The man of true genius who studies science in consequence of its application,—pointing out to himself a definite end, will make use of all the instruments of investigation which are necessary for his purposes; and in the search of discovery, he will rather pursue the plans of his own mind than be limited by the artificial divisions of language. Following extensive views, he will combine together mechanical, chemical, and physiological knowledge, whenever this combination may be essential; in consequence his facts will be connected together by simple and obvious analogies, and in studying one class of phænomena more particularly, he will not neglect its relations to other classes.

But chemistry is not valuable simply in its connections with the sciences, some of which are speculative and remote from our habitual passions and desires; it applies to most of the processes and operations of common life; to those processes on which we depend for the gratification of our wants, and which in consequence of their perfection and extension by means of scientific principles, have become the sources of the most refined enjoyments and delicate pleasures of civilized society.

Agriculture, to which we owe our means of subsistence, is an art intimately connected with chemical science. For though the common soil of the earth will produce vegetable food, yet it can only be made to produce it in the greatest quantity, and of the best quality, in consequence of the adoption of methods of cultivation dependent upon scientific principles. The knowledge of the composition of soils, of the food of vegetables, of the modes in which their products must be treated, so as to become fit for the nourishment of animals, is essential to the cultivation of land; and his exertions are profitable and useful to society, in proportion as he is more of a chemical philosopher. Since, indeed, this truth has been understood, and since the importance of agriculture has been generally felt, the character of the agriculturist has become more dignified and more refined. No longer a mere machine of labour, he has learned to think and to reason. He is aware of his usefulness to his fellow-men; and he is become at once the friend of nature and the friend of society.

The working of metals is a branch of technical chemistry; and it would be a sublime though a difficult task to ascertain the effects of this art upon the progress of the human mind. It has afforded to man the powers of defence against savage animals; it has enabled him to cultivate the ground, to build houses, cities, and ships, and to model much of the surface of the earth after his own imaginations of beauty. It has furnished instruments connected not only with his sublime enjoyments, but likewise with his crimes and his miseries; it has enabled him to oppress and destroy, to conquer and protect.

The arts of bleaching and dyeing, which the habits and fashions of society have made important are purely chemical. To destroy and produce colours, to define the causes of the changes they undergo, and to exhibit the modes in which they may be rendered durable, demand an intimate acquaintance with chemistry. The artist who merely labours with his hands, is obliged to theory for his discovery of the most useful of his practices; and permanent and brilliant ornamental colours which rival the most beautiful tints of nature, are artificially composed from their elements by means of human inventions.

Tanning and the preparation of leather are chemical processes, which, though extremely simple, are of great importance to society. The modes of impregnating skin with the tanning principle of the vegetable kingdom, so as to render it strong and insoluble in water, and the methods of preparing it for this impregnation have been reduced to scientific principles. And if the improvements resulting from new investigations have not been uniformly adopted by manufacturers, it appears to be owing rather to the difficulty occurring in inducing workmen to form new habits, to a want of certain explanations of the minutiæ of the operations, and perhaps in some measure to the common prejudice against novelties, than to any defect in the general theory of the art as laid down by chemical philosophers, and demonstrated by their experiments.

But amongst the chemical arts, few perhaps are more important than those of porcelain and glass making. To them we owe many of those elegant vessels and utensils which have contributed to the health and delicacy of civilized nations. They have furnished instruments of experiments for most of the sciences, and consequently have become the remote causes of some of the discoveries made in those sciences. Without instruments of glass, the gases could never have been discovered, or their combinations ascertained; the minute forms and appearances of natural objects could not have been investigated; and, lastly, the sublime researches of the moderns concerning heat and light would have been wholly lost to us.

This subject might be much enlarged upon; for it is difficult to examine any of our common operations or labours without finding them more or less connected with chemistry. By means of this science man has employed almost all the substances in nature either for the satisfaction of his wants or the gratification of his luxuries. Not contented with what is found upon the surface of the earth, he has penetrated into her bosom, and has even searched the bottom of the ocean for the purpose of allaying the restlessness of his desires, or of extending and increasing his power. He is to a certain extent ruler of all the elements that surround him; and he is capable of using not only common matter according to his will and inclinations, but likewise of subjecting to his purposes the ethereal principles of heat and light. By his inventions they are elicited from the atmosphere; and under his control they become, according to circumstances, instruments of comfort and enjoyment, or of terror and destruction.

To be able indeed to form an accurate estimate of the effects of chemical philosophy, and the arts and sciences connected with it, upon the human mind, we ought to examine the history of society, to trace the progress of improvement, or more immediately to compare the uncultivated savage with the being of science and civilization.

Man, in what is called a state of nature, is a creature of almost pure sensation. Called into activity only by positive wants, his life is passed either in satisfying the cravings of the common appetites, or in apathy, or in slumber. Living only in moments he calculates but little on futurity. He has no vivid feelings of hope, or thoughts of permanent and powerful action. And unable to discover causes, he is either harassed by superstitious dreams, or quietly and passively submissive to the mercy of nature and the elements. How different is man informed through the beneficence of the Deity, by science and the arts! Knowing his wants, and being able to provide for them, he is capable of anticipating future enjoyments, and of connecting hope with an infinite variety of ideas. He is in some measure independent of chance or accident for his pleasures. Science has given to him an acquaintance with the different relations of the parts of the external world; and more than that, it has bestowed upon him powers which may be almost called creative; which have enabled him to modify and change the beings surrounding him, and by his experiments to interrogate nature with power, not simply as a scholar, passive and seeking only to understand her operations, but rather as a master, active with his own instruments.

But, though improved and instructed by the sciences, we must not rest contented with what has been done: it is necessary that we should likewise do. Our enjoyment of the fruits of the labours of former times should be rather an enjoyment of activity than of indolence; and, instead of passively admiring, we ought to admire with that feeling which leads to emulation.

Science has done much for man, but it is capable of doing still more; its sources of improvement are not yet exhausted; the benefits that it has conferred ought to excite our hopes of its capability of conferring new benefits; and in considering the progressiveness of our nature, we may reasonably look forward to a state of greater cultivation and happiness than that we at present enjoy.

As a branch of sublime philosophy, chemistry is far from being perfect. It consists of a number of collections of facts connected together by different relations; but as yet it is not furnished with a precise and beautiful theory. Though we can perceive, develope, and even produce, by means of our instruments of experiment, an almost infinite variety of minute phænomena, yet we are incapable of determining the general laws by which they are governed; and in attempting to define them, we are lost in obscure, though sublime imaginations concerning unknown agencies. That they may be discovered, however, there is every reason to believe. And who would not be ambitious of becoming acquainted with the most profound secrets of nature, of ascertaining her hidden operations, and of exhibiting to men that system of knowledge which relates so intimately to their own physical and moral constitution?

The future is composed merely of images of the past, connected in new arrangements by analogy, and modified by the circumstances and feelings of the moment; our hopes are founded upon our experience; and in reasoning concerning what may be accomplished, we ought not only to consider the immense field of research yet unexplored, but likewise to examine the latest operations of the human mind, and to ascertain the degree of its strength and activity.

At the beginning of the seventeenth century very little was known concerning the philosophy of the intimate actions of bodies on each other; and before this time, vague ideas, superstitious notions, and inaccurate practices, were the only effects of the first efforts of the mind to establish the foundations of chemistry. Men either were astonished and deluded by their first inventions so as to become visionaries, and to institute researches after imaginary things, or they employed them as instruments for astonishing and deluding others, influenced by their dearest passions and interests, by ambition, or the love of money. Hence arose the dreams of alchemy concerning the philosopher's stone, and the elixir of life. Hence, for a long while the other metals were destroyed or rendered useless by experiments designed to transmute them into gold; and for a long while the means of obtaining earthly immortality were sought for amidst the unhealthy vapours of the laboratory. These views of things have passed away, and a new science has gradually arisen. The dim and uncertain twilight of discovery, which gave to objects false or indefinite appearances, has been succeeded by the steady light of truth, which has shown the external world in its distinct forms, and in its true relations to human powers. The composition of the atmosphere, and the properties of the gases, have been ascertained; the phænomena of electricity have been developed; the lightnings have been taken from the clouds; and lastly, a new influence has been discovered, which has enabled man to produce from combinations of dead matter effects which were formerly occasioned only by animal organs.

The human mind has been lately active and powerful; but there is very little reason for believing that the period of its greatest strength is passed; or even that it has attained its adult state. We find in all its exertions not only the health and vigour, but likewise the awkwardness of youth. It has gained new powers and faculties; but it is as yet incapable of using them with readiness and efficacy. Its desires are beyond its abilities; its different parts and organs are not firmly knit together, and they seldom act in perfect unity.

Unless any great physical changes should take place upon the globe, the permanency of the arts and sciences is rendered certain, in consequence of the diffusion of knowledge by means of the invention of printing; and those words which are the immutable instruments of thought, are become the constant and widely-diffused nourishment of the mind, the preservers of its health and energy. Individuals, in consequence of interested motives or false views, may check for a time the progress of knowledge; moral causes may produce a momentary slumber of the public spirit; the adoption of wild and dangerous theories, by ambitious or deluded men, may throw a temporary opprobrium on literature; but the influence of true philosophy will never be despised; the germs of improvement are sown in minds even where they are not perceived, and sooner or later the spring-time of their growth must arrive.

In reasoning concerning the future hopes of the human species, we may look forward with confidence to a state of society in which the different orders and classes of men will contribute more effectually to the support of each other than they have hitherto done. This state indeed seems to be approaching fast; for in consequence of the multitiplication of the means of instruction, the man of science and the manufacturer are daily becoming more nearly assimilated to each other. The artist who formerly affected to despise scientific principles, because he was incapable of perceiving the advantages of them, is now so far enlightened, as to favour the adoption of new processes in his art, whenever they are evidently connected with a diminution of labour. And the increase of projectors, even to too great an extent, demonstrates the enthusiasm of the public mind in its search after improvement. The arts and sciences also are in a high degree cultivated, and patronized by the rich and privileged orders. The guardians of civilization and of refinement, the most powerful and respected part of society, are daily growing more attentive to the realities of life; and, giving up many of their unnecessary enjoyments in consequence of the desire to be useful, are becoming the friends and protectors of the labouring part of the community. The unequal division of property and of labour, the difference of rank and condition amongst mankind, are the sources of power in civilized life, its moving causes, and even its very soul; and in considering and hoping that the human species is capable of becoming more enlightened and more happy, we can only expect that the great whole of society should be ultimately connected together by means of knowledge and the useful arts; that they should act as the children of one great parent, with one determinate end, so that no power may be rendered useless, no exertions thrown away. In this view we do not look to distant ages, or amuse ourselves with brilliant, though delusive dreams concerning the infinite improveability of man, the annihilation of labour, disease, and even death. But we reason by analogy from simple facts. We consider only a state of human progression arising out of its present condition. We look for a time that we may reasonably expect, for a bright day of which we already behold the dawn.

So far our considerations have been general; so far we have examined chemistry chiefly with regard to its great agency upon the improvement of society, as connected with the increasing perfection of the different branches of natural philosophy and the arts. At present it remains for us only to investigate the effects of the study of this science upon particular minds, and to ascertain its powers of increasing that happiness which arises out of the private feelings and interests of individuals.

The quantity of pleasure which we are capable of experiencing in life appears to be in a great measure connected with the number of independent sources of enjoyment in our possession. And though one great object of desire, connected with great exertions, must more or less employ the most powerful faculties of the soul; yet a certain variety of trains of feeling and of ideas is essential to its health and permanent activity. In considering the relations of the pursuit of chemistry to this part of our nature, we cannot but perceive that the contemplation of the various phænomena in the external world is eminently fitted for giving a permanent and placid enjoyment to the mind. For the relations of these phænomena are perpetually changing; and consequently they are uniformly obliging us to alter our modes of thinking. Also the theories that represent them are only approximations to truth; and they do not fetter the mind by giving to it implicit confidence, but are rather the instruments that it employs for the purpose of gaining new ideas.

A certain portion of physical knowledge is essential to our existence; and all efficient exertion is founded upon an accurate and minute acquaintance with the properties of the different objects surrounding us. The germ of power indeed is native; but it can only be nourished by the forms of the external world. The food of the imagination is supplied by the senses, and all ideas existing in the human mind are representations of parts of nature accurately delineated by memory, or tinged with the glow of passion, and formed into new combinations by fancy. In this view researches concerning the phænomena of corpuscular action may be said to be almost natural to the mind, and to arise out of its instinctive feelings. The objects that are nearest to man are the first to occupy his attention: from considering their agencies on each other he becomes capable of predicting effects; in modifying these effects he gains activity; and science becomes the parent of the strength and independence of his faculties.

The appearances of the greater number of natural objects are originally delightful to us, and they become still more so, when the laws by which they are governed are known, and when they are associated with ideas of order and utility. The study of nature, therefore, in her various operations must be always more or less connected with the love of the beautiful and sublime; and in consequence of the extent and indefiniteness of the views it presents to us, it is eminently calculated to gratify and keep alive the more powerful passions and ambitions of the soul, which, delighting in the anticipation of enjoyment, is never satisfied with knowledge; and which is as it were nourished by futurity, and rendered strong by hope.

In common society, to men collected in great cities, who are wearied by the constant recurrence of similar artificial pursuits and objects, and who are in need of sources of permanent attachment, the cultivation of chemistry and the physical sciences may be eminently beneficial. For in all their applications they exhibit an almost infinite variety of effects connected with a simplicity of design. They demonstrate that every being is intended for some definite end or purpose. They attach feelings of importance even to inanimate objects; and they furnish to the mind means of obtaining enjoyment unconnected with the labour or misery of others.

To the man of business, or of mechanical employment, the pursuit of experimental research may afford a simple pleasure, unconnected with the gratification of unnecessary wants, and leading to such an expansion of the faculties of the mind as must give to it dignity and power. To the refined and fashionable classes of society it may become a source of consolation and of happiness, in those moments of solitude, when the common habits and passions of the world are considered with indifference. It may destroy diseases of the imagination, owing to too deep a sensibility; and it may attach the affections to objects, permanent, important, and intimately related to the interests of the human species. Even to persons of powerful minds, who are connected with society by literary, political, or moral relations, an acquaintance with the science that represents the operations of nature cannot be wholly useless. It must strengthen their habits of minute discrimination; and by obliging them to use a language representing simple facts, may tend to destroy the influence of terms connected only with feeling. The man who has been accustomed to study natural objects philosophically, to be perpetually guarding against the delusions of the fancy, will not readily be induced to multiply words so as to forget things. From observing in the relations of inanimate things fitness and utility, he will reason with deeper reverence concerning beings possessing life; and perceiving in all the phenomena of the universe the designs of a perfect intelligence, he will be averse to the turbulence and passion of hasty innovations, and will uniformly appear as the friend of tranquillity and order.

A SYLLABUS

OF A

COURSE OF LECTURES ON CHEMISTRY,

DELIVERED AT THE

ROYAL INSTITUTION OF GREAT BRITAIN.

ADVERTISEMENT.

It is generally admitted that the best method of teaching the sciences is to begin with simple facts, and gradually to proceed from them to the more complicated phænomena.

In the following pages, which contain the Outlines of a Course of Lectures on Chemistry, an attempt has been made to employ such a method. Hence the abstruse doctrines concerning the imponderable fluids have been separated from the history of simple chemical action; and the applications of the science from the science itself.

The classification of substances adopted, is founded rather upon facts than analogies; and in consequence, certain bodies have been placed amongst the simple principles, which, from their resemblance to other bodies of known composition, have been generally arranged in the class of compounds.

This is an imperfection, but on the principles assumed it could not easily be avoided. And it will be fortunate for the Author if a discerning public should not discover many more important imperfections.

HUMPHRY DAVY.

Royal Institution,
January 5th, 1802.

SYLLABUS

OF

A COURSE OF LECTURES.

PART I.

THE CHEMISTRY OF PONDERABLE SUBSTANCES.

DIVISION I.

OF THE CHEMICAL POWERS, AND THE MODES OF THEIR APPLICATIONS.

I. *Of the general Logic of Science.*

The sciences are classes of different facts associated together by analogy.

The theories which represent them are connected propositions, in which, by means of that faculty of the mind named abstraction, one term is made to represent a number of other terms, which themselves stand for ideas.

By means of artificial arrangements or theories, the business of thinking is materially expedited; and the power of calculating concerning new relations of facts, rendered simple and easy.

2. *Of the Nature of Chemistry.*

Chemistry is that part of the science of nature which relates to those intimate actions of bodies upon each other, by which their appearances are altered and their individuality destroyed.

The knowledge of those actions is derived from our sensations; and the facts that represent them are classed according to the corpuscular theory.

3. *Of the Corpuscular Theory.*

The different bodies in nature are composed of particles or minute parts, individually imperceptible to the senses. When these particles are similar, the bodies they constitute are denominated simple, and when they are dissimilar, compound.

The chemical phænomena result from the different arrangements of the particles of bodies: and the powers that produce these arrangements are repulsion or the agency of heat, and attraction.

By repulsion, the particles of bodies tend to separate from each other.

By attraction, they tend to come in contact with each other.

4. *Of the Power of Repulsion or Caloric.*

The expanding power, or the power of repulsion, is capable of being communicated by the particles of one body to those of other bodies; and the laws of its communication constitute the laws of temperature. See Part II. Div. I.

It acts in uniform opposition to attraction; and the peculiar forms of aggregation in bodies depend upon the different agencies of these powers.

Bodies exist either in the solid, fluid, or aëriform states;

and, according as they are made to receive, or communicate the power of repulsion, they expand or contract. Solids, on a certain increase of the repulsive power of their particles, become fluids, and fluids, gases. Likewise, by a diminution of repulsive power, gases become fluids, and fluids, solids.

The cause of the phænomena of repulsion has been lately generally named caloric; and it is, by a number of philosophers, supposed to be a peculiar ethereal substance.

5. *Of Attraction.*

Attraction either acts upon similar particles, and then it is denominated the attraction of aggregation, or upon dissimilar particles, when it is named the attraction of composition, or chemical affinity.

The most important general facts relating to the attraction of composition may be classed in six propositions.

(1) The attraction of composition is capable of uniting a number of dissimilar particles.

(2) The particles of different simple bodies have different affinities for each other.

(3) The agency of the attraction of composition on the particles of bodies, is inversely as that of the attraction of aggregation.

(4) The force of the attraction of composition is influenced by the numbers of the combining particles; i. e. by the masses of the acting bodies.

(5) The forces of the attraction of composition in different substances, are diminished in different ratios, by the agency of caloric or the power of repulsion.

(6) In all cases of combination, the volume of the

combining bodies is either diminished, or increased; and, in general, in consequence, they gain a power of increasing, or diminishing, respectively the volumes of the bodies in contact with them; or, in common language, caloric is either given out, or absorbed during chemical combination.

6. *Of Chemical Operations.*

Though the powers of attraction and repulsion are parts of an arbitrary system, yet the laws by which they are supposed to act are simple expressions of facts. Guided by those laws, the chemist is capable of imitating the operations of nature, and of producing new operations, so as to exhibit certain substances or principles apparently simple, and to ascertain their combinations.

The methods by which these purposes are effected, are synthesis and analysis.

By synthesis compound substances are formed by the artificial union of different principles.

By analysis compound substances are resolved into their constituent principles.

7. *Of the Instruments of Experiment.*

To effect chemical compositions and decompositions, nothing more is required than to bring the particles of the bodies, which are the subjects of experiment, into the sphere of their mutual attractions.

Towards this end, the mechanical division of them into small parts is employed; and likewise, in certain cases, the agency of caloric.

The vessels in which bodies are operated upon, must be composed of substances for which they have no affinity.

The most important instruments in the chemical apparatus, are, furnaces, lamps, crucibles; mercurial and water pneumatic troughs, and gasometers; graduated glass jars, retorts, receivers; the balance, the air-pump, the electrical machine, the barometer, and the thermometer.

DIVISION II.

OF UNDECOMPOUNDED SUBSTANCES OR SIMPLE PRINCIPLES.

1. *Of the Classification of Undecompounded Substances.*

Though the corpuscular theory supposes the existence of bodies composed of similar particles, yet we are not certain that any such bodies have been yet examined. The simple principles of the chemists are substances which have not been hitherto composed or decomposed by art; and they are elements, only in relation to other known substances.

As they are the *sensible* agents of chemistry, before we can examine the nature of compound bodies, or particular phænomena of composition or decomposition, it is necessary that we should be acquainted with their characteristic properties, and with certain of the modes in which they are procured.

Forty-two simple principles are at present acknowledged. Considered with regard to the similarity of some of their physical properties, they may be divided into six classes: I. Permanent gases possessed of no acid properties. II. Solid inflammable bodies having no metallic properties. III. Metals. IV. Earths. V. The fixed alkaline substances. VI. The undecompounded acids.

2. *First Class.*

The first class of simple substances contains only three bodies—oxygen, hydrogen, and nitrogen. They are permanent gases at all known temperatures. They have no taste, smell, or colour, and are very little absorbable by water.

(1) OXYGEN GAS constitutes $\frac{1}{5}$ part of the air of the atmosphere. It is produced pure from oxygenated muriate of potash by heat. It eminently supports combustion. The cubic inch weighs ·34 pts. of a grain.

(2) HYDROGEN GAS is produced when water is made to act on ignited zinc or iron. It burns when intensely heated in contact with oxygen; and is the lightest of the known gases, weighing, in the cubic inch, only ·024 pts. of a grain.

(3) NITROGEN GAS constitutes about $\frac{4}{5}$ of the atmosphere. It is evolved during the action of nitric acid on animal substances. It is not inflammable; it does not support combustion. A cubic inch of it weighs about ·3 pts. of a grain.

3. *Second Class.*

Phosphorus, sulphur, and carbon, compose the second class of simple principles. These bodies do not differ considerably in their specific gravities, and are nonconductors of electricity, and insoluble in water.

(1) PHOSPHORUS is obtained from phosphoric acid by means of ignited charcoal. It is transparent. Its

colour is light yellow; and its specific gravity is to that of water as 2·033 to 1. It becomes liquid at the temperature of 99° Fahrenheit, and aëriform at that of 554°. It burns with a feeble blue flame in the atmosphere at, or even below, 50°, and with an intensely vivid light at 122°.

(2) SULPHUR is found abundantly in nature, and it may be procured in a very pure form from sulphuret of potash by means of muriatic acid. It is of a bright yellow colour. It melts at a heat a little above that of boiling water, and becomes aëriform at 600° Fahrenheit. At a temperature scarcely above that of its fusion it burns with a feeble blue flame, and at the heat of ignition with an intensely vivid flame. Its specific gravity is about 2.

(3) CARBON is found pure in nature, in the form of diamond; but it has not yet been produced from any of its compounds. It is, perhaps, the hardest known body; it is extremely transparent. It burns at a very high temperature; and after becoming black and opaque, is converted into gas. Its specific gravity is about 3·5.

4. *Third Class.*

The metals at present known amount to twenty-one. They are platina, gold, silver, mercury, copper, tin, lead, iron, zinc, antimony, bismuth, arsenic, cobalt, nickel, manganese, tungsten, uranium, molybdena, titanium, tellurium, chrome.

The metals are possessed of specific gravities superior to those of all other simple substances. They are opaque, brilliant in their appearance, insoluble in water, and conductors of electricity.

(1) **Platina** is procured by intensely heating the oxyde of platina produced by nitro-muriatic acid, with charcoal. It is of a light grey colour. It is malleable, and is the hardest of the metals after iron. It becomes fluid at a very high degree of heat. It does not burn in the atmosphere. Its specific gravity is 22·5, so that it is the heaviest body in nature.

(2) **Gold** is found pure in different parts of the globe. It is of a bright yellow colour. It fuses when ignited to whiteness. It is the most malleable and ductile of the metals. Its specific gravity is 19·3.

(3) **Silver** is found in nature pure, and combined with different substances. It is the whitest of the metals. Its malleability and ductility are less than those of gold. Its specific gravity is about 10·51. It is fused more readily than gold.

(4) **Mercury** is found pure; likewise it is procured from cinnabar. It is the only metal which is fluid at the common temperatures of the atmosphere: it does not become solid, except at 40° below 0°; at 600° it boils. Its colour is analogous to that of silver. Its specific gravity is 13·568.

(5) **Copper** is found native; likewise it is extracted from sulphuret of copper. It is of a light red colour. Its specific gravity is 8·584. It melts at the white heat. It is malleable and ductile.

(6) **Tin** is procured when the oxyde of tin is heated to whiteness with charcoal. It is of a white colour, but little duller than that of silver. It melts long before it becomes ignited, i. e. at about 410° Fahrenheit. It is very malleable, but imperfectly ductile. Its specific gravity is 7·299.

(7) **Lead** is generally obtained by separation from the sulphuret of lead by heat. It is of a bluish white colour,

and soon loses its metallic lustre when exposed to the air. It becomes fluid at 540° Fahrenheit. It is malleable, but its ductility is imperfect. Its specific gravity is 11·352.

(8) IRON is obtained from the oxyde of iron, by intensely heating it with charcoal. It is of a pale grey colour. Its specific gravity is 7·8. It is fusible only at an intense degree of heat; but becomes extremely soft and ductile when only ignited. It is attracted by the magnet. It soon becomes covered with a brown rust when exposed to the atmosphere.

(9) ZINC is generally procured from the sulphuret of zinc, or from the carbonates of zinc, which are found abundantly in nature. It is rather whiter than lead. Its specific gravity is 7·19. It fuses as soon as it is ignited, and boils before it is white hot; and at this temperature, burns with a vivid flame.

(10) ANTIMONY is generally procured from sulphuret of antimony. It is nearly of the colour of lead. Its specific gravity is 6·86. It melts soon after ignition, and becomes covered with a white oxyde. It is very little ductile or malleable.

(11) BISMUTH is found in a native state; likewise it is obtained from sulphuret of bismuth. It is of a dull yellow colour, a little inclined to red. It is not malleable. Its specific gravity is 9·822. After tin and tellurium, it is one of the most fusible of the metals.

(12) ARSENIC may be procured from the white oxyde of arsenic, by heating it with oil, or with charcoal, in close vessels. It is white in its pure form, but soon becomes tarnished by exposure to the air. It sublimes at the temperature of ignition with great rapidity, and burns with a bluish flame. Its specific gravity is 8·31.

(13) COBALT is obtained from smalt (a blue glass con-

taining the oxyde of cobalt) by igniting it with charcoal and soda. It is of a grey colour. It is very difficult of fusion. Its specific gravity is 7·645.

(14) **Nickel** is procured from an ore named kupfer nickel. Its colour is rusty light grey. Its specific gravity is 8·96. It is difficultly fusible. When perfectly pure it is not magnetic.

(15) **Manganese** is procured by an intense heat from the oxyde of manganese by means of charcoal. It is of a dull white colour. It is fused only with extreme difficulty. Its specific gravity is 7. It is not at all malleable.

(16) **Tungsten** is obtained by various processes from the tungstate of lime, and from wolfram, a mineral found in Cornwall. It is very difficultly fused. Its specific gravity is 8·34.

(17) **Uranium** is procured from pech-blende, and from its carbonate by different processes. It is grey, with a tinge of brown. It has never been fused into a consistent mass. Its specific gravity is 6·44.

(18) **Molybdena** has been obtained with very great difficulty from the molybdic acid. Its properties are but little known. Its specific gravity is said to be 6.

(19) **Titanium** is obtained from the oxyde of titanium by intense ignition of it with charcoal. It is very difficult of fusion. Its colour is red; and its specific gravity unknown.

(20) **Tellurium** is procured from the aurum paradoxicum. It is of a bright grey colour. It pulverizes under the hammer. It is the most fusible and volatile of the metals after mercury. Its specific gravity is 6·115.

(21) **Chrome** is obtained from the red lead of Siberia (the chromate of lead). Its properties are little known. Its colour is whitish; and it is very difficult of fusion.

5. *Fourth Class.*

The earths are distinguished from all other bodies by their infusibility, their insolubility in water, their incombustibility, and their want of conducting power with regard to electricity. They are four in number, silex, alumine, zircone, glucine.

(1) SILEX is obtained from rock-crystal, and other stones, after they have been fused with fixed alkalies, and acted upon by muriatic acid. It differs from the other earths in being acted upon by no acid but the flouric.

(2) ALUMINE is obtained from solution of sulphate of alumine by potash. Its colour is white. In its common state it contracts in volume by heat; and at an intensely high temperature it becomes softened. It is combinable with the acids.

(3) ZIRCONE is obtained from the jargon of Ceylon by the fusion of it with a fixed alkali, and particular treatment with an acid. It is white, and diffusible through water, to which it communicates a gelatinous appearance. It combines with the acids. Its specific gravity is 4·3.

(4) GLUCINE is procured from the beryl. It resembles alumine in its physical properties; but its chemical properties are very different. It forms sweet-tasted salts with the acids.

It is said that two new earths have been lately discovered, denominated Augustine and Ittria.

The AUGUSTINE is considered as a peculiar substance, on the authority of Professor Tromsdorf. It is procured from the beryl of Georgen-stadt. And it forms tasteless salts with the acids.

ITTRIA has been examined by M. Ekeburg and Professors Vauquelin and Klaproth. The salts it forms with the acids are sweet like those formed by glucine; but it is not soluble in the caustic alkalies. It was first announced as a peculiar substance by M. Gadolin.

6. *Fifth Class.*

It has been thought expedient to call such undecompounded substances alkaline as possess a certain degree of solubility in water, and the power of combining with the acids, and with sulphur; and of rendering green vegetable blues.

Potash, soda, strontian, barytes, lime, and magnesia, are the only known fixed alkaline substances.

(1) Potash is obtained from the common caustic potash of commerce by solution in alcohol, and evaporation. It was formerly named the fixed vegetable alkali. It is of a white colour. Its taste is intensely caustic, and it acts upon the animal fibre. It becomes fluid at a red heat; but it is volatile only at a very high temperature. It is extremely soluble in water.

(2) Soda is obtained from muriate of soda (sea salt) by means of litharge. It is purified by treatment with alcohol, in the same manner as potash. Its taste and causticity, as well as many of its other properties, are analogous to those of that alkali; but it possesses less affinity for the acids. It is fusible at a temperature a little below that of ignition. It was formerly called the fixed fossil alkali.

(3) Strontian is procured from the carbonate of strontian when it is intensely ignited with charcoal. It is white. Its specific gravity is greater than that of potash or of soda. It is much less soluble in water than those alkalies. It is infusible. Certain of its combina-

tions when brought in contact with bodies in combustion, communicate a vivid redness to their flames.

(4) **Barytes** is obtained from nitrate of barytes by the long application of a high degree of heat. Its taste is caustic, like that of strontian. It is nearly four times as heavy as water. Of all the alkaline substances, it possesses the strongest affinity for the acids. It is less soluble in water than strontian.

(5) **Lime** is procured from the carbonate of lime (marble) by a strong degree of heat. It is white and opaque. It is unalterable in the fire. It resembles strontian and barytes in most of its physical properties; but it is less soluble in water than either of those earths (requiring 500 times its weight of that fluid for its solution); likewise it has less affinity for the acids.

(6) **Magnesia** is obtained from sulphate of magnesia by treatment with potash or soda. It is exhibited in the form of a white impalpable powder, possessing very little taste or smell. It is soluble in about 2000 times its weight of water. It has less affinity for the acids than any of the other solid alkaline substances, and it forms with them very soluble salts. It is perfectly unalterable in the fire.

7. *Sixth Class.*

We are acquainted with three undecompounded acids; the muriatic acid, the flouric acid, and the boracic acid. They are combinable with water and the alkalies; and possessed of the power of rendering vegetable blues red.

(1) **Muriatic acid** is procured from muriate of soda by means of sulphuric acid. It is a permanent gas at all known temperatures. It is heavier than atmospheric

air. It is soluble to a great extent in water. Its taste is very pungent and sour.

(2) Fluoric acid is obtained from fluate of lime by means of sulphuric acid. It dissolves silicious earth, and renders it aëriform; therefore it cannot be preserved pure in glass vessels. Its taste and smell are analogous to those of muriatic acid; and, like that acid, it is a gas at all known temperatures. It is extremely soluble in water, and combinable not only with the alkaline, but likewise with the earthy substances.

(3) Boracic acid is procured from alkaline borate of soda by means of sulphuric acid. It is a white solid body, possessing very little taste and no smell. It is fusible when dry at the red heat; and when moist, it is even volatile at a much lower temperature. It is soluble in 50 times its weight of boiling water.

DIVISION III.

OF BODIES COMPOSED OF TWO SIMPLE SUBSTANCES, OR BINARY COMPOUNDS.

1. *Arrangement of Binary Compounds.*

The simplest chemical actions of the undecompounded substances on each other, are exerted in the production of binary compounds.

Of these compounds, some are found in nature, and others are produced by art, either directly, by bringing the principles that compose them into apparent contact at a certain temperature; or, indirectly, by analytical processes, in which bodies more compounded are the subjects of experiment.

The binary compounds, if we consider their relations to each other, and to the general chemical arrangement of substances, may be divided into six classes.

I. Compounds containing oxygen. II. ——Hydrogen. III. ——Sulphur. IV. ——The Metals. V. ——The Earths. VI. ——The Undecompounded Acids.

2. *First Class.*

Of all known bodies, oxygen has the greatest tendency to combination. It enters into union with a vast number of simple substances. Many of its compounds are possessed of analogous properties. It has been generally supposed to be the acidifying principle; and the history of its chemical agencies constitutes the antiphlogistic theory.

The binary compounds of oxygen are either decomposable acids possessing the sour taste, and the power of reddening vegetable blues, and of uniting with the alkalies; or oxydes, which in general are combinable with the acids, insoluble or sparingly soluble in water, and possessed of little taste or smell. These different substances will be treated of in their relations to their different bases.

(1) COMBINATION of OXYGEN with HYDROGEN. *Water*, or oxyde of hydrogen, is produced whenever hydrogen gas is burnt in contact with oxygen gas. 15 grains of hydrogen, combined by slow combustion with 85 grains of oxygen, produce 100 grains of pure water. Water is a fluid at all temperatures between 32° and 212°. When cooled below 32° it becomes solid, and forms a mass of crystals. When heated above 212° it becomes a gas, and in that state is much lighter than the air of the atmosphere.

The physical properties of water are well known. It is possessed of great powers of combination, and acts a principal part in the chemical changes that take place upon the surface of the globe, and in the atmosphere.

(2) COMBINATIONS of OXYGEN with NITROGEN. When the electric spark is passed for a long while through a mixture of oxygen gas, and nitrogen gas, *nitric acid* is formed. This substance is permanently aëriform at common temperatures. 100 cubic inches of it weigh about 76 grains. It is extremely soluble in water; 1 grain of water being capable of condensing about 10 grains of acid gas, forming with it a fluid of specific gravity 1·52. Nitric acid is a very powerful and useful chemical agent. For purposes of application, it is generally obtained from nitrate of potash (nitre of commerce) by means of sulphuric acid. 100 grains of nitric acid consist of about 71 oxygen, and 29 of nitrogen.

Nitrous gas, or nitric oxyde, is an elastic fluid permanent at all known temperatures. It is produced whenever nitric acid is decomposed by certain metallic bodies, such as copper, silver, &c. Its specific gravity is to that of atmospheric air, as 1·093 to 1. It is very little soluble in water. It combines with oxygen at common temperatures, producing an orange-coloured gas, which is nitric acid with excess of nitrous gas, i. e. *nitrous acid.* Nitrous gas is composed of 56 parts oxygen, and 44 nitrogen. It is readily absorbed by the green sulphates, and muriates of iron. Pyrophorus takes fire in it at common temperatures: and phosphorus continues to burn when introduced into it in a state of vivid inflammation.

Nitrous oxyde, or gaseous oxyde of azote, is obtained when nitrate of ammonia is decomposed at any temperature near 400° Fahrenheit. It is permanently aëriform. The cubic inch weighs ·5 pts. of a gr. It is possessed of a faintly sweetish taste, and a slight but agreeable odour. All the combustible bodies burn in it with vivid light at high temperatures. It does not diminish when mingled with nitrous gas. It is soluble in twice its volume of water, and in less than half its volume of most of the inflammable fluids. It is combinable, when in a nascent state, with potash and soda. 100 grains of it are composed of 37 oxygen, and 63 nitrogen.

(3) COMPOUNDS of OXYGEN and PHOSPHORUS. *Phosphoric acid,* or the most oxygenated compound of oxygen and phosphorus, is produced when sulphuric acid is made to act upon phosphate of lime (i. e. earth of bones). It is likewise procured when phosphorus is burnt in atmospheric air, at a temperature above 122°. Phosphoric acid is a solid at temperatures below those of ignition. It is very soluble in water. It is inodorous; and possesses no volatility. It is composed of nearly 1 of phosphorus to 1·6 of oxygen.

Phosphorus acid, or the least oxygenated compound of oxygen and phosphorus is produced during the slow combustion of phosphorus in the atmosphere at common temperatures. It is a fluid body, inodorous, and possessed of a strong affinity for water.

(4) COMBINATIONS of OXYGEN with SULPHUR. Sulphur, like phosphorus, combines with oxygen in two proportions, and forms sulphuric and sulphureous acids.

Sulphuric acid is produced during the vivid combustion of sulphur in oxygen gas, and likewise during the decomposition of nitrate of potash by heated sulphur. In its common state it appears in the form of a transparent oleaginous fluid, nearly twice as heavy as water. At a very low temperature it becomes solid. It is composed of about 1·7 parts sulphur and 1 part oxygen. It acts with great power upon animal and vegetable substances; which, by abstracting a portion of its oxygen, convert into sulphureous acid.

Sulphureous acid is a permanently aëriform fluid at the common temperatures of the atmosphere; but it has been rendered fluid by a high degree of artificial cold, aided by a strong pressure. It is absorbable by $\frac{1}{8}$ of its volume of water. Its composition has not yet been accurately ascertained. It is generally obtained for accurate experiments from the decomposition of heated sulphuric acid by mercury. The cubic inch weighs ·73 pts. of a gr. It extinguishes flame. When suffered to remain for a long while in contact with oxygen gas, it is converted into sulphuric acid.

(5) Compounds of oxygen and carbon. Three compounds containing oxygen and carbon, in different proportions, are known. Charcoal, gaseous oxyde of carbon, and carbonic acid.

Charcoal is procured pure by passing alcohol through a tube heated red. It is carbon in the first degree of oxygenation. It forms a considerable part of the solid matter of organized bodies, and it is obtained from them mixed with other substances by the action of heat. Its colour is intensely black. It has no taste or smell. It is a perfect conductor of electricity. It is solid at all known temperatures. It burns with the production of vivid white light in oxygen gas. It is perfectly insoluble in water. It is capable of absorbing certain quantities of different known gases, which are liberated from it by the action of heat.

Gaseous oxyde of carbon is obtained by the action of ignited charcoal on certain metallic oxydes, such as those of zinc and iron. It is carbon in the second degree of oxygenation. It is devoid of taste and smell. It is very little absorbable by water. It burns in contact with atmospheric air with a lambent blue flame. Its specific gravity is to that of common air nearly as 22 to 23. It is composed of about 9 parts carbon and 21 parts oxygen.

Carbonic acid is produced when charcoal, or diamond is burned in pure oxygen: likewise it is obtained when muriatic acid is made to decompose carbonate of lime. It has a pleasant smell, and a faintly acidulous taste. It is a permanent gas at all known temperatures. It is soluble in half its volume of water. It extinguishes flame. The cubic inch weighs about ·46 pts. of a gr. It is carbon perfectly oxygenated, and combined with four parts of oxygen.

(6) COMBINATIONS of OXYGEN with the ACIDIFIABLE METALS. The acidifiable metals are, arsenic, tungsten, molybdena, chrome, and, as it is said, cobalt.

Arsenic is capable of combining with oxygen in two proportions, so as to form the arsenious and arsenic acids.

The *arsenious acid*, or as it has been generally called, white oxyde of arsenic, is procured by the action of oxygen gas on metallic arsenic. Its taste is disagreeably acrid, and its smell is analagous to that of garlic. It is soluble in 15 parts of boiling water. Its specific gravity is 3·706. It is volatile at the temperature of 283°. It is said to be composed of 93 parts of arsenic and 7 of oxygen.

The *arsenic acid* is procured by the action of nitric acid upon the arsenious acid. Its taste is sour. Its colour is white. It fuses at a red heat, but it is not volatile. It is said to be composed of 91 parts of arsenic and 9 of oxygen.

One combination of oxygen with tungsten only is known. The *tungstic acid* is procured by the fusion of tungstate of lime with carbonate of potash, and subsequent treatment of the mixture with nitric acid. It exists in the form of a white powder. Its taste is faintly acrid. Its specific gravity is 3·6. It is neither fusible nor volatile at any known temperature. It is soluble in 20 parts of boiling water.

Molybdena combines with oxygen in two proportions, so as to produce the molybdic oxyde and the molybdic acid.

The *molybdic oxyde* is procured when molybdena is intensely heated in contact with oxygen. It is white, and volatile. It is easily converted into molybdic acid, by treatment with nitric acid.

The *molybdic acid* is soluble in 500 parts of water. Its specific gravity is 3·4. Its taste is distinctly sour.

Chrome exists in two states combined with oxygen. —*The oxyde of chrome* is of a green colour. It is procured by the action of heat and light on the chromic acid.

The *chromic acid* is obtained by the decomposition of the chromate of lead found in Siberia. It is of a red colour, and has a peculiar metallic taste. It is soluble in water.

Cobalt has long been known as combined with oxygen in the state of an *oxyde*, capable of communicating a fine blue colour to glass; but the existence of the *acid of cobalt* has been only lately proved by the experiments of Brugnatelli. It is produced from what he calls the ammoniuret of cobalt. It is soluble in water, and has a distinctly sour taste.

(7) COMBINATIONS of OXYGEN with the OXYDIFIABLE METALS. Manganese, zinc, iron, tin, lead, antimony,

bismuth, nickel, titanium, tellurium, copper, and mercury, are capable of combining with oxygen gas, when they are exposed to it at different high temperatures; but their *oxydes* are, in general, obtained for common purposes, either from certain ores found in nature, or from the agency of different acids on the metallic bases.

Silver, gold, and platina, do not act upon oxygen gas except when they are ignited by the galvanic spark. The *oxyde of silver* is obtained by treatment of the metal by nitric acid and potash. The *oxydes of gold* and *platina* are procured by means of oxymuriatic acid.

The *oxyde of uranium* is found in uranite.

Oxygen is capable of combining in different proportions with many of the metals, and of forming with them, oxydes possessed of distinct properties.

Amongst the most remarkable of the metallic oxydes, are the *red* and *black oxydes of iron*, containing respectively, 47, and 28 per cent. of oxygen; the *red, black,* and *white oxydes of mercury,* of which the red gives out oxygen gas when exposed to heat: the *red, yellow, and grey, oxydes of lead;* the *black oxyde of manganese;* and the *white oxyde of antimony.*

The metallic oxydes in general are insoluble in water, tasteless and inodorous. Many of them are fusible at high degrees of heat, and a few of them are volatile. They are all of less specific gravity than their bases. In certain states of oxygenation they are combinable with acids.

(8) COMBINATION of OXYGEN with MURIATIC ACID. *Oxygenated muriatic acid* is procured when muriatic acid is distilled from black oxyde of manganese, or red oxyde of lead. Its taste is acrid. It renders vegetable blues white, differing in this respect from the other acids. It is a gas at common temperatures; but it may be con-

densed by a moderate degree of cold. Its colour is light yellow. It is absorbable by water. Most of the combustible bodies burn in it. It is combinable with the fixed alkaline substances. It gives out oxygen gas when acted upon by vivid light. Its specific gravity is much greater than that of atmospheric air.

3. *Second Class.*

Hydrogen appears to be capable of combining with only three simple bodies besides oxygen; nitrogen, sulphur, and phosphorus. For the hydrocarbonates, which were formerly supposed to consist wholly of hydrogen and carbon, contain, as it would seem from some late experiments, a portion of oxygen. See Div. IV. Sec. 2. Its compounds are not possessed of many analogous properties; one of them is an alkali, and another an acid.

(1) Compound of hydrogen and nitrogen. *Ammonia* or volatile alkali is obtained by the action of lime upon muriate of ammonia; likewise it is formed when nascent hydrogen is exposed to nitrogen gas at a low temperature. It is a permanent gas at common temperatures, weighing in the cubic inch about ·18 pts. of a gr. Its smell is highly pungent; and its taste burning and acrid. It renders green, vegetable blues. It extinguishes flame. It produces white fumes when brought in contact with the volatile acids. It is extremely soluble in water, 75 grains of water being capable of absorbing 25 grains of gas, forming with it a fluid of specific gravity ·908. Ammonia is decomposed into its constituent parts by the action of electricity, or of a high degree of heat. It is compounded of one part hydrogen and five parts nitrogen.

(2) COMPOUND of HYDROGEN and SULPHUR. *Sulphurated hydrogen* or hepatic gas is formed when hydrogen gas is passed over heated sulphur. It is obtained for common purposes by the action of an acid on solution of sulphuret of potash. It is a permanent elastic fluid. Its smell is extremely fœtid. Its taste is sour, it reddens vegetable blues, it combines with the alkalies, and is very soluble in water; so that it is a true acid. It burns, when highly heated in contact with oxygen gas, with a blue flame, depositing sulphur. It is decompounded into its constituent principles by the electric spark. The cubit inch weighs ·34 pts. of a gr.

(3) COMBINATION of HYDROGEN with PHOSPHORUS. *Phosphorated hydrogen* is formed by the action of phosphorus upon the heated aqueous solution of potash. It is likewise obtained by the action of water upon the phosphuret of lime, a substance formed by passing phosphorus in vapour through ignited lime. It is a permanent gas, soluble in about four times its volume of water. It is possessed of the peculiar property of inflaming when brought in contact with oxygen gas at common temperatures. It is decomposable by the electric spark.

4. *Third Class.*

Sulphur is possessed of great powers of combination. It enters into union with all the metals, except gold, platina, titanium, and probably, chrome. It combines with the alkaline substances, and with phosphorus. Its acid compounds, containing oxygen, and hydrogen, have already been noticed.

(1) COMBINATIONS of SULPHUR with the METALS. The greater number of the metallic sulphurets are found in

nature. They may be made artificially, by bringing sulphur in contact with the metals, at different high temperatures; and during the process, heat and light are evolved. They are solids, in general possessed of a high degree of specific gravity. They are opaque, and often brilliant in their appearance like the metals. They are conductors of electricity. They have no taste or smell. They are all decomposable at certain degrees of heat.

Of the metallic sulphurets, the best known are the *sulphuret of iron* or martial pyrites, the *sulphuret of zinc* or blende, the *sulphuret of lead* or galena, and the *sulphurets of copper*, *tin*, *arsenic*, and *mercury*.

Almost every metal is capable of combining with many different proportions of sulphur.

(2) COMPOUNDS containing SULPHUR and the FIXED ALKALINE SUBSTANCES. The alkaline sulphurets or the hepars of sulphur, may be obtained by the fusion of sulphur with the different alkaline substances, or by the decomposition of alkaline sulphates by charcoal at a high degree of heat. They are solid bodies, in general opaque, and of a red, or brownish red colour. They are of considerable specific gravity. They burn, when intensely heated, in contact with the atmosphere. They undergo peculiar changes from the action of water. They are decomposable by the acids. The *sulphurets of potash*, *of soda*, *of strontian*, and *of magnesia*, are not possessed of any specific properties worthy of particular notice. The *sulphurets of barytes*, and *of lime*, become phosphorescent after having been exposed to light.

(3) COMPOUND of SULPHUR and PHOSPHORUS. Sulphur and phosphorus are capable of combining in different proportions. To effect their union with safety, they must be fused together under hot water. The

sulphurets of phosphorus are yellowish, and less transparent in proportion as they contain a larger quantity of sulphur. They are all more fusible than sulphur. They are so combustible that they inflame in the atmosphere by mere friction.

5. *Fourth Class.*

The binary compounds containing the metals, which have not been already described, are the metallic phosphurets, the carburets, and the alloys.

(1) Combinations of phosphorus with the metals. Phosphorus is capable of combining in different proportions with the greater number of the metallic substances. The *phosphurets* generally are obtained by exposing the metals to phosphorus, at the time that it is produced from ignited phosphoric acid, by means of charcoal. They are opaque, of great specific gravity, and usually possessed of the metallic splendour. They are fusible at different high temperatures, and they burn at those temperatures when in contact with oxygen.

(2) Combinations of metals with carbon. Iron, zinc, and manganese, are the only metals supposed to be capable of combination with carbon.

When diamond and iron are intensely heated together, the *carburet of iron* or steel is formed. This substance is obtained for use, from the cementation of iron with charcoal. It is fusible at a high degree of heat. It is harder than iron. It is capable of receiving an extremely fine polish. It is very combustible.

Plumbago, or the *hypercarburet of iron*, is supposed to be a combination of carbon and iron, with probably a minute portion of oxygen. It is found in nature.

I is of a black glossy colour. It is infusible. It burns, when intensely heated, in contact with the atmosphere.

The properties of the *carburets of zinc,* and of *manganese,* have been but little examined. It is likely, that they, as well as the hypercarburets of iron, contain a minute quantity of oxygen.

(3) BINARY COMBINATIONS of METALS with ONE ANOTHER. The *binary alloys* are formed by bringing two metals possessed of affinity for each other together, one of them at least being in a state of fusion. The alloys are analogous to the simple metals in all their physical properties. Their number is almost infinite, for when metallic substances are possessed of the power of attracting each other chemically, they are capable of combining in a number of different proportions. The chemical properties of alloys have been very little studied, and no definite knowledge is obtained concerning the change of volume taking place during the different combinations of metals. The most important of the binary metallic compounds are *brass,* which is composed of about three parts of copper and one of zinc; *bronze,* which is a compound of copper and tin; the *fusible compounds of lead;* and the *amalgums of mercury.*

6. *Fifth Class.*

Certain of the earths are possessed of affinities for one another: all of them except zircone, are capable of combining with some of the fixed alkaline substances; and that body, as well as alumine, and glucine, is acted upon by the undecompounded acids.

(1) BINARY COMPOUNDS containing EARTHS only. The *combination of silex* and *alumine* may be effected by

mingling their alkaline solutions together. The *compound of jargon* and *silex* is formed when these earths are intensely heated in contact with one another. The mutual attractions of the other earths have not been much examined.

(2) COMBINATIONS of EARTHS with ALKALINE SUBSTANCES. When equal parts of potash, or of soda, and of silex are fused together, they combine and form the compound denominated *glass,* the properties of which are well known. When one part of silex is united, by fusion, to three parts of potash, or of soda, a substance is formed which is soluble in water, and which forms with it the *liquor silicum.*

Alumine and glucine are combinable with potash and soda, both when they are dry, and in aqueous solution at certain degrees of temperature.

Barytes, strontian, or lime, when intensely heated in certain proportions with silex, combine with it and form vitreous compounds.

(3) The COMBINATIONS of the EARTHS with the SIMPLE ACIDS, will be considered in the next section.

7. *Sixth Class.*

The binary compounds containing the simple acids, are possessed of very analogous properties. They have been called *compound salts;* and under this name, have been generally arranged with substances containing the decomposable acids.

(1) COMBINATIONS of the SIMPLE ACIDS with FIXED ALKALINE SUBSTANCES. The simple acids are capable of combining with all the fixed alkaline substances, when their aqueous solutions are brought into contact with them at common temperatures; and the com-

pounds when deprived of water become permanent solids.

The compounds of the muriatic acid and the fixed alkaline substances, or the *fixed alkaline muriates*, are possessed in general of a bitter taste. They are white semipellucid bodies, regularly crystallized. They are extremely soluble in water.

Amongst the compounds of fluoric acid and the fixed alkaline substances, the *fluates of potash* and *of soda* are soluble in water, and nearly insipid; the *fluates of strontian, barytes, lime,* and *magnesia,* are tasteless substances, not combinable with water.

The combinations of the boracic acid with potash and soda, or the *borates of potash* and *soda* are crystallized, solid, substances, soluble in water. The *borate of soda* with *excess of alkali* is the borax of commerce.

The *borates of barytes, strontian, lime,* and *magnesia,* have been very little examined. They are white, solid substances, but little combinable with water.

(2) COMPOUNDS containing UNDECOMPOUNDED ACIDS and EARTHS. All the earths except silex, are dissolved when acted upon by an aqueous solution of muriatic acid. The compounds formed are called *muriates.* When deprived of water they exist in the solid form. Generally they are white and transparent. They are possessed of no smell. Their taste is bitter, or astringent.

Fluoric acid combines with all the earths, when it is brought in contact with them at common temperatures, and forms compounds called *fluates.* The *fluate of silex* exists permanently in the aëriform state. The properties of the *fluates of zircone, alumine,* and *glucine,* have been very little examined.

The compounds of the earths and the *boracic acid,* are called *borates.* In general they are difficultly soluble in water. They are possessed of little taste and no smell.

DIVISION IV.

OF BODIES COMPOSED OF MORE THAN TWO SIMPLE SUBSTANCES, OR TERNARY COMPOUNDS, QUATERNARY COMPOUNDS, &c.

1. *Classification of Substances composed of more than two Simple Substances.*

Very few of the substances composed of more than two simple principles are capable of being formed by art, immediately from their elements. In general, they are either found in organized bodies, or are produced during their spontaneous or artificial decomposition. We are acquainted with their nature chiefly from analysis. Considering their composition, and the mode in which they are procured, they may be divided into five classes.

I. Oxydes with bases compounded chiefly of hydrogen and carbon. II. Acids composed chiefly of hydrogen, oxygen, and carbon. III. Oxydes with bases compounded chiefly of nitrogen, hydrogen, and carbon. IV. Acids composed chiefly of oxygen, nitrogen, hydrogen, and carbon. V. Compounds containing earths, and alkalies, or metals.

2. *First Class.*

The oxydes containing hydrogen and carbon are found in general in the vegetable kingdom. Their composition and their properties are very different and various. Amongst them may be found, gases, fluids, and solids. In general, they are combustible, easily decomposable by heat, and non-conductors of electricity.

(1) HYDRO-CARBONATES. *Heavy hydro-carbonate* is one of the products evolved during the decomposition of spirits of wine by heated sulphuric acid. It is a permanent gas at all known temperatures. It burns, when heated in contact with the atmosphere, with a blue flame. It is insoluble in water. The cubic inch weighs ·26 pts. of a gr.

Light hydro-carbonate is obtained when water is made to act upon ignited charcoal. Its properties are analogous to those of heavy hydro-carbonate. The cubic inch weighs ·15 pts. of a gr.

The proportions between the constituent parts of the hydro-carbonates have not hitherto been accurately ascertained. The existence of hydrogen, carbon, and oxygen, in them is proved when they are decomposed by heated sulphur; for in this case, charcoal and sulphuretted hydrogen are formed.

(2) ALCOHOL is obtained in its purest form from ardent spirits, by their treatment with potash, and subsequent distillation. It is an inflammable fluid. It is possessed of a strong affinity for water, and is seldom procured perfectly devoid of that fluid. Its specific gravity, when in its purest state, is about ·829. It contains a larger proportion of carbon and oxygen than the hydro-carbonates, for when it is passed through a tube heated red, it is decompounded into heavy hydro-carbonate and charcoal. Alcohol has never yet been ren-

dered solid by any degree of cold. It becomes a gas at the temperature of 176°.

(3) ETHER is produced during the action of sulphuric, nitric, or muriatic acid upon alcohol. It is the lightest known fluid body, its specific gravity being only ·739. It is possessed both of a strong and peculiar smell and taste. It is soluble in water. It does not become solid by artificial cold. It boils at 96°. It is very inflammable. It is decompounded by being passed through a tube heated red, affording products analogous to those produced by the decomposition of alcohol. It differs from that body in composition, probably by containing more oxygen and hydrogen.

(4) OILS are obtained by expression, or distillation, from different vegetable and animal substances. In general they are capable of freezing at low temperatures. They are immiscible with water. They are usually of less specific gravity than water. They are inflammable. They are decomposed when passed through ignited tubes; the products being chiefly charcoal and hydrocarbonate.

The oils procured in different manners are extremely different in their properties; and it is probable that they owe their peculiarities to the different substances which they hold in solution.

The oils called fixed, appear to be generally combined with mucilage; whereas those denominated volatile, contain vegetable aromatic matters.

(5) SUGAR is obtained from the inspissated juice of certain plants, such as the sugar-cane, and the white beet. Its physical properties are well known. It is combustible. It is decomposable, like most of the other vegetable products, by a high degree of heat. It is capable

of forming alcohol by fermentation. Its composition has not been hitherto exactly ascertained.

(6) Resin is exuded from the barks of certain trees. It is very little vapid or odorous. It is inflammable. It is soluble in alcohol, but not in water. It is capable of being rendered fluid by heat. It appears to differ from volatile oil, only by containing more oxygen.

(7) Wax in its composition strongly resembles resin. It is collected by bees, probably from the pollen of flowers. Its properties are well known.

(8) Gum is found plentifully in many vegetables. It is often exuded from their barks. It is a transparent substance; very brittle, tasteless, and inodorous. It is very slightly inflammable. It is soluble in water; but insoluble in alcohol. It contains less oxygen than sugar; consisting chiefly of carbon and hydrogen, with probably a little nitrogen. Gum under certain modifications of its principles, assumes the forms of MUCILAGE, and of FECULA.

(9) Tannin, or the tanning principle, is obtained when the precipitate obtained from a decoction of galls, by means of muriate of tin, is acted upon by sulphuretted hydrogen. It appears in the form of a light brown pulverulent mass. Its taste is bitter. It is soluble in water, and in alcohol. It is decomposable by heat. It is possessed of affinity for many of the metallic oxydes. Its composition is not accurately known.

(10) Extract is obtained by evaporating the infusion of saffron in water. It is extremely soluble both in water and alcohol. It is insoluble in sulphuric ether. It is softened by a moderate degree of heat, though it is not fusible. At high temperatures it is decomposed.

(11) The WOODY FIBRE and COLOURING MATTERS of vegetables have been very little examined, but their

composition is supposed to be analogous to that of the substances which have been just described.

3. *Second Class.*

The acid substances chiefly composed of oxygen, hydrogen, and carbon, belong more particularly to the vegetable kingdom. They form a numerous class of bodies, and are possessed of very analogous physical properties. In general they are soluble in water, decomposable by heat, possessed of the sour taste, and capable of rendering vegetable blues red.

(1) ACETOUS ACID or vinegar, is formed during the fermentation of wine. Its taste is pleasantly sour; its smell is agreeable. It is a fluid easily rendered aëriform by heat. At a high temperature it is decomposable. It is capable of being deprived of a portion of carbon by distillation from metallic oxydes, when it becomes possessed of new properties, and is called ACETIC ACID. Certain of the empyreumatic oils when dissolved in acetous acid materially alter its properties. The substances that were formerly termed pyromucous, pyroligneous, and pyrotartaric acids, are wholly composed of acetous acid and empyreumatic oils.

(2) TARTARIC ACID is procured from acidulous tartrate of potash, which is found in wines, by treatment with lime and sulphuric acid. It is a solid substance, generally composed of needle-formed crystals. Its taste is very sour. It is soluble in water, and decomposable by heat.

(3) OXALIC ACID is generally obtained from the juice of the wood sorrel, oxalis acetosella. It may likewise be obtained from the action of nitric acid upon sugar

and other vegetable oxydes. It contains more oxygen than tartaric acid. It is a crystallized solid, soluble in half its weight of boiling water. Of all the acids it is possessed of the strongest affinity for lime.

(4) Citric acid is obtained from the juice of lemons, when it is treated with lime and sulphuric acid. It is a solid crystallized body; extremely soluble in water, and in its aqueous solution is possessed of a very pleasant acid taste.

(5) Malic acid is extracted from the juice of ripe fruits by means of lime and acetite of lead. It is easily decomposed by heat. It is converted, by nitric acid, into oxalic acid.

(6) Gallic acid is obtained by sublimation from the aqueous extract of galls. It generally appears in the form of small grey crystals. It precipitates the red oxyde of iron black from its solutions. Its taste is very acrid.

(7) Succinic acid is obtained by the distillation of amber. It is crystallized in three-sided prisms of a beautiful white colour. It is inflammable.

(8) Benzoic acid is procured from benzoin, storax, and other substances, by means of heat. Its smell is aromatic, and its taste extremely pungent. It is crystallized in compressed prisms. It is very fusible, and volatile. It burns in contact with oxygen. It is soluble in nitric acid.

(9) Camphoric acid is produced during the distillation of camphor with nitric acid. It crystallizes in parallelopipeds. It is very little soluble in water. It burns in contact with the atmosphere, forming new compounds, wholly gaseous.

(10) Suberic acid is formed by the distillation of nitric acid from wood. It is soluble in about fifty times

its weight of water. Its taste is slightly sour. It is easily decomposed by heat.

(11) Mucous acid, or saccholactic acid is obtained by the distillation of gum or mucilage with nitric acid, and likewise from sugar of milk. It appears in the form of a white powder, very little soluble in water. It is decomposed with more difficulty than most of the other vegetable acids.

4. *Third Class.*

The compounds possessed of no acid properties, chiefly containing oxygen, hydrogen, carbon, and nitrogen, are in general found in the animal kingdom. The relative proportions of the principles that compose them are unknown. One of their most characteristic properties is the facility with which their composition is altered.

(1) Gelatine is obtained from different animal matters, and particularly from skin, by means of boiling water. In its solid form it appears as a semiductile, transparent, substance, without taste or smell. It is extremely soluble in warm water; but insoluble in alcohol. It is combustible; and decomposable by heat. It is soluble in the acids. It is precipitated from its aqueous solutions by nitromuriate of tin, and likewise by tannin. Combined with tannin it forms an insoluble compound, analogous to leather.

(2) Albumen is found plentifully in the eggs of birds, and in other animal productions. In its natural state it appears in the form of a transparent viscous fluid, possessed of no distinct taste or smell. Its most characteristic property is its coagulation by a heat of 165° into a permanent solid mass. Albumen, when liquid, is com-

binable with water; but when coagulated, it seems to have little affinity for that fluid. Coagulated albumen is soluble in solutions of alkaline substances. Albumen is capable of being combined with tannin. It contains a little sulphur united with its other constituent parts

(3) **Fibrine** is procured from the blood of animals by repeated washing of the coagulum. It is of a white colour. It is insoluble in water, and in alcohol. The alkaline aqueous solutions, when cold, do not dissolve it; but when very concentrated, they decompose it. It is soluble in many of the acids.

(4) **Urea** is a crystallized substance obtained from urine. It is soluble in water and in alcohol. It is combinable with certain of the acid and alkaline solutions.

(5) **Gluten** is obtained from wheat flour, when all its other constituent parts have been separated by water. Though of vegetable origin, it bears a strong analogy to the substances which have been just described; and evidently contains a considerable quantity of nitrogen. It is insoluble in alcohol. It is combinable with heated alkaline solutions.

5. *Fourth Class.*

Amongst the acid substances, chiefly containing oxygen, hydrogen, carbon, and nitrogen, some are found native in animal solids and fluids, others are produced during their natural or artificial decomposition. The native animal acids are the formic acid, the bombic acid, the laccic acid, the selbacic acid, and the uric acid. The acids produced by the decomposition of animal substances by heat, are the prussic and zoonic acids. The lactic acid is formed during the fermentation of milk.

(1) The FORMIC ACID is found in a particular species of ants (the formica rustica); and it is obtained by their distillation. It is extremely analogous to the acetic acid. It has a strong smell, and a very sour and caustic taste. In its common form it is fluid, but it may be easily volatilised. It is soluble in alchol, and is decomposed by nitrous acid.

(2) The BOMBIC ACID is obtained from the silkworm, and from certain species of moths. Its taste is slightly sour; and it reddens vegetable blues. Its properties are very little known.

(3) LACCIC ACID is obtained by a low degree of heat from a substance called white lac, formed by certain insects of the coccus tribe. It is a fluid possessed of a salt, bitterish, taste. It is capable of being crystallized. It boils at 200°. It is easily decomposed at a higher temperature.

(4) SEBACIC ACID is procured by treating a mixture of lime and suet, which has been exposed to heat, by sulphuric acid. It has an acrid taste, and a very pungent smell. It is decomposable by heat. When mixed with nitric acid it enables it to dissolve gold.

(5) URIC ACID is obtained from an alkaline solution of the urinary calculus, by means of acetous acid. It crystallizes in thin plates. Its colour is brown. It has very little taste or smell. It is soluble in three hundred parts of boiling water. It combines readily with alkaline substances. It is acted upon by nitric acid, to which it communicates a pink colour.

(6) PRUSSIC ACID is formed when ammoniacal gas is passed over ignited charcoal. It is obtained for common purposes from the decomposition of alkaline prus-

siates, by acids. It is exceedingly volatile. Its smell is peculiar, and its taste is sweetish, but acrid. It is easily decompounded by heat, when united to the alkalies, producing carbonate of ammonia. It has a very strong affinity for the metallic oxydes. Combined with red oxyde of iron it forms a bright blue substance, known by the name of prussian blue.

(7) Zoonic acid is procured from animal substances by distillation; and likewise from gluten. It is purified by treatment with lime and phosphoric acid. Its smell is like that of roast meat. Its taste is acrid. It is easily volatilised. It produces a white precipitate in the solutions of acetite of lead, and nitrate of mercury.

(8) Lactic acid is procured from sour milk by treatment of it with lime and alcohol. It is a solid body, very soluble in water. Its chemical properties are very little known.

6. *Fifth Class.*

The fifth class of the more compounded substances, may be divided into metallic compounds, and earthy and alkaline compounds.

(1) The metallic compounds, containing more than two simple principles, are extremely numerous, but of very little importance in the chemical arrangement. Their properties in general have not been studied. Amongst the ternary and quarternary alloys in common use, are the alloys of *bismuth* with *lead* and *tin*, which are extremely fusible; the *alloys* of *mercury* with *zinc*, *tin*, and *lead*, used in electrical experiments; different compound *alloys* of *copper*. There are no known ternary combinations of the inflammable bodies and metals.

(2) The earths are capable of combining with each other, and with the alkaline substances, in many different proportions. A very great number of their compounds is found in nature; and many of them are made in different artificial processes. The compounds of alumine, silex, lime, and magnesia, in different proportions, are capable of being softened, and, in certain cases fused, by heat.

In general the earthy, or alkaline substances, which are infusible alone, lose this property by being mixed together, and become fluid at the time that they enter into combination.

DIVISION V.

OF SUBSTANCES COMPOSED OF DIFFERENT COMPOUND BODIES, OR OF COMPOUND BODIES AND SIMPLE BODIES.

1. *Classification of Substances containing different Compound Bodies, &c.*

The substances considered in this division are in general capable of being composed either from different compound bodies, and from compound bodies and simple bodies, or of being decomposed into them. Hence they are considered as owing their formation to peculiar attractions of undecompounded principles, modified by a previous combination. They exist for the greater part in nature: many of them are capable of being formed artificially. If we derive the methods of arranging them from their physical relations, they may be considered under four classes.

I. Saline compounds. II. Mineral substances. III. Vegetable substances. IV. Animal substances.

2. *First Class.*

The saline compounds are substances containing, as one of their constituent parts, at least, an acid, an alkali, or an oxyde. They are very numerous, and are capable of being formed, and decomposed, artificially. In general they are more or less soluble in water. They are often possessed of taste. They are chiefly incombustible. When solid they are nonconductors of electricity. They may be considered under three genera. 1. Compounds containing acids. 2. Compounds containing alkalies. 3. Compounds containing oxydes.

(1) COMPOUNDS containing ACIDS. The acids are capable of combining with the fixed alkaline substances, with ammonia, with the metallic oxydes, and with all the earths except silex, when they are merely brought in contact with them; and the bodies they form with them have been generally called compound salts. The compound salts are usually transparent, solid, crystallized, substances. Their names are derived from the acids, and the bases, that constitute them. They are not of such importance in the general arrangement of chemistry as to require description individually; and they may be considered in *species* possessed of analogous properties, and corresponding in number with the acids.

a. The sulphuric, and sulphureous acids combined with the alkaline substances, &c. form salts called respectively *sulphates* and *sulphites*, which are convertible into sulphurets by ignition with charcoal.

b. The compounds of the nitric acid are called *nitrates*. They are decomposable by heat, and detonate when mingled with inflammable substances.

c. Many of the compounds containing muriatic acid, or the *muriates*, have been described in Div. III. Sect. 6. and the rest have no important characters.

d. The compounds containing phosphoric, and phosphorous acids, or the *phosphates* and *phosphites* are not decomposable by heat; and they are known from the disengagement of their acids, by means of sulphuric acid.

e. The compounds containing carbonic acid, or the *carbonates*, are in general decomposable by heat; and they retain, more or less, the characters of their bases.

f. The compounds of the fluoric acid, or the *fluates*, have already, in part, been described, Div. III. Sect. 6. In general they evolve a dense white vapour on the contact of sulphuric acid, which corrodes glass.

g. Many of the compounds of the boracic acid, or the *borates*, have been noticed in the same division as the fluates. They are all fusible at high temperatures, and easily decompounded by different acids.

h. The *arseniates* and *arsenites*, or the salts containing the arsenic and arsenious acids, are known by the arsenical smell they emit when brought in contact with hot charcoal.

i. The properties of the *tungstates*, and of the *molybdates*, or the salts containing the tungstic, and molybdic acids, are very little known. The compounds of the chromic acid or the *chromates* are characterized by their peculiar colours.

k. The *acetites* or the compounds of the acetous acid, are decomposable by heat, and they are known by their acid when it is disengaged by means of sulphuric acid.

l. The compounds of the tartaric acid or the *tartrates*, are ascertainable by their faintly acidulous taste, and the facility with which they are decomposed by heat.

m. The *oxalates*, or the compounds of the oxalic acid, are distinguished by the power of their acid to decompose all calcareous salts.

n. The compounds of the citric, the malic, and the benzoic acids, or the *citrates, malates, benzoates,* are known only from the disengagement and examination of their acids.

o. The *gallates*, or the compounds of the gallic acid; when metallic, are characterized by their striking colours; and when alkaline, by their power of precipitating red oxyde of iron black from all its solutions.

p. The compounds of camphoric, suberic, mucous, and succinic, acid, or the *camphorates, suberates, mucites,* and *succinates* are very imperfectly known, and they are chiefly distinguished by simple decomposition, when their acids are evolved.

q. The *formiates*, the *bombiates*, the *laccates*, the *sebates,* and the *lactates,* or the compounds containing the formic, and the bombic, the laccic, the sebacic, and the lactic, acids have in general been very little examined, and they are only known by the disengagement of their acids.

r. The *prussiates,* or the compounds containing prussic acid, are distinctly characterized by their various colours, or by their powers of producing colours, when mingled with certain metallic solutions.

s. The *zoonates,* or the compounds containing zoonic acid, are sufficiently distinguished by the animal smell produced during the disengagement of their acid.

t. The compounds containing oxygenated muriatic acid, or the *oxygenated muriates,* are known by their power of detonating by concussion, when mingled with inflammable substances; and likewise from the disengagement of their acid.

u. The *hydrosulphurets*, or the combinations of sulphuretted hydrogen, are known by their peculiar smell and colour, and the facility with which they are decomposed.

All these compound salts may be considered as binary combinations of acids with single bases, and may be called double salts. But there are other substances which consist of an acid and two bases. These compounds have as yet been very little examined. Many of them contain magnesia and ammonia, or ammonia and metallic oxydes. They are called triple salts.

(2) SALINE BODIES containing ALKALINE SUBSTANCES. The alkaline substances are capable of combining with many other bodies besides the acids. They enter into union with oils, fat, albumen, alcohol, and other compound bodies.

Amongst the alkaline compounds most worthy of notice are, the soaps, the hydrogenated sulphurets, and the substances containing alkalies and metallic oxydes.

a. The *soaps* are formed by the combination of volatile or fixed oils or fat with the alkaline substances. Amongst them the *soaps* containing *potash*, *soda*, and *ammonia*, are soluble in water, decomposable by heat, and possessed of an acrid taste and a peculiar smell. The *soaps* containing *barytes*, *strontian*, *lime*, and *magnesia*, are nearly insoluble in water, and possessed of no important properties.

b. The *fixed alkaline hydrogenated sulphurets* are produced, when the alkaline sulphurets are acted upon by water. They are compounds of sulphuretted hydrogen, and sulphurets. They are soluble in water. They are readily decompounded by acids, which combine with the alkali, when the sulphuretted hydrogen and sulphur are rendered free. They are of a yellow colour, and possessed of a disagreeable smell and a nauseous taste. They blacken the skin when applied to it. They readily absorb oxygen gas; and in consequence, have been successfully employed as eudiometrical substances.

Ammonia is capable of combining with sulphur and sulphuretted hydrogen, so as to form a compound soluble in water, called *hydrogenated sulphuret of ammonia.* This compound is usually formed by the distillation of a mixture of lime, muriate of ammonia, and sulphur.

c. The *substances containing alkalies,* and *metallic oxydes* will be immediately noticed.

(3) SALINE BODIES containing OXYDES. Many of the metallic oxydes are capable of combining with the alkalies; and the substances they form with them are possessed of very singular properties. Amongst the compounds of the metallic oxydes and alkalies, the most important are the ammoniurets of silver, gold, mercury, and copper.

a. The *ammoniuret of silver* or ammoniacal fulminating silver is formed when oxyde of silver is digested for some time in caustic solution of ammonia. It is a crystallized substance; and it detonates with astonishing violence when slightly heated, or even when gently touched.

b. The *ammoniurets of gold, mercury,* and *copper,* are procured in a manner similar to that in which the ammoniuret of silver is formed. The ammoniuret of gold fulminates when it is briskly rubbed, or heated pretty strongly. The ammoniuret of copper does not fulminate. It is of a beautiful blue colour.

c. The oxydes of mercury and silver, when treated with nitric acid and alcohol, are capable of becoming powerful detonating compounds. And in this state, appear to be combined with oxalic acid, and nitrous etherized gas.

The *fulminating mercury*, and *fulminating silver*, are both opaque bodies, one white, and the other grey. They explode at temperatures much below those of ignition. The discovery of these substances is owing to Mr. Howard.

The metallic oxydes are capable of combining with oils; but the properties of the compounds they form with them have been very little studied.

3. *Second Class.*

The substances composed of different compounds of the earths, alkaline substances, and metals, have been classed under the general name of mineral bodies, for they exist for the most part in nature. The accurate classification of them, according to a minute observation of their external properties, chemical composition, and relations to each other and to different natural and artificial substances, belongs to an extensive branch of chemical science named *mineralogy*. In this place, they will be noticed only in their connexions with the substances, which may be considered as their constituent parts, mentioned in the preceding sections.

They may be divided into compounds chiefly metallic, which are generally ores; or compounds chiefly earthy, which are principally stones.

(1) The COMPOUNDS CHIEFLY METALLIC. The metallic oxydes, alloys, and sulphurets, may be considered as forming the bases of the very compounded metallic substances.

The metallic oxydes are often found in nature, combined with silicious and aluminous earth, and likewise with certain of the fixed alkaline substances forming different ores. Thus, the oxyde of iron is found combined with alumine and lime in the aluminous ironstone.

The compounds containing metallic oxydes are extremely various in their composition: and their properties are very little analogous. Amongst them may be mentioned the hematites, calamine, and molybdate of lead.

The metallic alloys and sulphurets are often found combined together in different ores. Thus the blendes or ores of zinc often contain copper and lead; and galena, or the sulphuret of lead is often united to silver. These combinations are as yet very little understood.

(2) The COMPOUNDS CHIEFLY CONTAINING EARTHS are in general divided into genera, which are named from the simple earth or alkaline substance of which they contain the largest proportion. The genera containing the greatest number of bodies are, 1. The silicious. 2. The aluminous. 3. The calcareous. 4. The magnesian. These genera, in the mineralogical system, apply not only to the more compounded substances, but likewise to the binary and ternary compounds, &c.

In the *silicious genus*, the most important of the more compounded stones are quartz, felspar, hornstone, carnelian, chalcedony, flint, &c. all of which are found, owing their colours to metallic oxydes.

The *aluminous genus* contains, amongst other substances, corundum, ruby, emerald, topaz, shistus, smectis, lithomarga, bole, lepidolite, sappare, talc, hornblende, wacken, trap, killas.

In the *calcareous genus* are classed the varieties of limestone, dolomite, the marlites, the fluates, phosphorites, &c. which are all, in fact, compound salts containing metallic oxydes, &c.

Amongst the stones belonging to the *magnesian genus* are the steatites, the serpentines, jade, abestus, chrysolite, &c.

(3) The earths and the alkaline and metallic substances, in their different compounds, constitute by far the greater portion of the known solid matter of the globe. And these compounds, in their natural arrangement, are found either collected in immense indurated, and often stratified masses, as rocks, or in smaller masses, as stones and pebbles, or in a state of loose mixture, as in soils.

4. *Third Class.*

The epidermis, the parenchyma, the cortical layers, the wood, the pith, the sap, and other substances found in the roots, trunks, leaves, flowers, and seeds of plants, appear for the most part, to be compounded of the oxydes and acids containing oxygen, hydrogen and carbon, of water, and different earths and salts. We are, however, very little acquainted with the arrangement of these their constituent parts.

We can only examine vegetable substances chemically in their dead state. Our analysis of them is generally made by heat, and we are wholly incapable of proving the accuracy of it by synthesis.

The organs of different vegetables, as far as they have been examined, differ as much in their composition, as in their external properties, so that it is impossible to speak with accuracy in any but general terms, of the nature of the substances that compose them.

(1) The SOLID PARTS OF PLANTS. The *epidermis* of plants in general, appears to be in a great measure formed of extract and woody fibre, combined with different earths and oxydes of iron.

The *parenchyma* and *cortical layers* in plants, very often contain tannin, gallic acid, mucilage, sugar, and resin.

The *wood* of plants, which is chiefly formed of woody fibre, likewise contains tannin, resin, mucilage, and gallic acid.

The composition of *flowers* is very little known. The pollen in them is composed of a very inflammable substance. Many of the *fruits* and *grains* contain large quantities of fecula, of sugar, and of different acids, always combined with water and woody fibre, and in certain instances with gluten.

The *soft matter* of the *leaves* of plants often contains extract and mucilage, and sometimes albumen. The *external surface* of leaves is sometimes thinly covered with wax.

(2) The FLUID PARTS. The *sap* in plants is chiefly water holding in solution different salts and acids, with a little sugar and mucilage.

The *other juices* contained in the vessels of plants, are very various in their composition. Amongst them may be found oils combined with mucilage, and colouring, and aromatic matters, and other peculiar fluids, capable of forming gum, resin, and other substances of the same kind, when exposed to the air.

5. *Fourth Class.*

The chemistry of animal substances is as yet in its infancy, and the only instrument it can employ is imperfect analysis. The animal organs in the only state in which they can become the subjects of experiment, even in the dead state, are constantly undergoing changes which cannot be accurately estimated; and consequently the account that can be given of their composition must be considered as more or less general, vague, and uncertain.

The more compounded substances which enter into their composition, and which are capable of being chemically examined, are either solids or fluids. Amongst the solids may be enumerated skin, muscular fibre, the matter of fat, the soft matter composing the nerves, membrane, cartilage, and bony matter. The principal fluids are, blood, chyle, bile, milk, the gastric and pancreatic juices, and the saliva.

These bodies, as far as they have been analysed, by reagents, and by heat, appear to consist in general of different proportions of the substances described in Div. IV. Sect. 4. and 6. combined, in unknown arrangements, and in general in organized forms, with water, mucilage, and different earths, and salts.

(1) The SOLID PARTS. In the skin, the epidermis appears to consist chiefly of albumen, gelatine, and phosphate of lime; and the cutis of gelatine, and fibrine, with a very little albumen.

The *muscular fibre* is almost wholly composed of fibrine, combined with gelatine, albumen, and probably certain neutral salts.

The *matter of fat* is chiefly composed of *pure* fat, and the sebacic acid. In the state in which it is found in animals, it is soft, and is possessed of no regular organized appearance.

The *soft matter* composing the nerves has been very little examined. In some of its properties it is analogous to albumen; but there is every reason to believe that its composition is extremely complicated.

Membrane and *cartilage* are chiefly composed of gelatine and albumen, with a minute quantity of phosphate of lime.

Bony matter is chiefly composed of phosphate of lime combined with gelatine, and sometimes with a little carbonate of lime and albumen.

(2) ANIMAL FLUIDS. *Blood* is found in two states, as arterial blood, which is of a bright vermilion colour; and as venous blood, which is of a dark red colour. The principal constituent parts of these two fluids are nearly the same; and they both, as soon as they are taken out of the living vessels, separate into two distinct parts, one of which is solid, the coagulum; and the other fluid, the serum. The coagulum consists of fibrine, and of colouring particles; of which the colouring particles are composed of water, albumen, gelatine, phosphate of iron, and soda. The serum is composed of albumen, gelatine, and certain neutral salts, held in solution by water. The red particles in the arterial blood appear to contain more oxygen than those in the venous blood; and this is probably one of the essential causes of the difference between the two fluids.

The composition of *chyle* is very little known. There is every reason to believe that its constituent principles are analogous to those of blood; and the theory of the conversion of chyle into blood is a most interesting subject for physiological investigation.

Bile is chiefly composed of animal oil combined with soda, and held in solution by water. It contains, likewise, albumen, and small portions of different compound salts.

Milk may be separated, by very simple processes, into three distinct parts, the serum, the coagulum or the caseous part, and the oily part or butter. The serum appears to be composed chiefly of water, holding in solution mucilage, sugar, and different salts. The caseous matter approaches near to albumen in its chemical properties; and the oily matter or butter, seems to consist chiefly of a pure oil, probably combined with a small quantity of mucilage and saccharine matter.

The chemical composition of the *gastric* and *pancreatic juices* is very little known.

The *saliva* appears to be chiefly composed of water, holding in solution mucilage, albumen, and minute portions of neutral salts.

DIVISION VI.

GENERAL PHÆNOMENA OF CHEMICAL ACTION.

1. *Classification.*

The phænomena connected with the composition and the decomposition of the compound bodies, described in the three last divisions, are capable of being generalized; and as far as they relate to the chemistry of ponderable substances, they may be explained by the propositions concerning the laws of attraction mentioned in Div. I. Sect 5.

All chemical action, which can be considered as resulting from the primary powers of ponderable substances, may be divided into four kinds. I. Simple combination. II. Compound combination. III. Simple decomposition. IV. Complex decomposition.

2. *Simple Combination.*

(1) Whenever two simple bodies enter into union, their attraction is mutual, and they appear to act upon each other with different forces. In considering these forces, they will be found to depend, not only upon the difference between the primary affinities of the substances for each other, but likewise upon the difference of their masses, that is, upon the number of different particles brought into the sphere of activity. Div. I. Prop. (1) and (4).

Instances of these expressions of facts may be found in the binary combinations of simple principles, Division III. Thus in the different oxydes of iron, the oxygen is condensed in the solid form; and it adheres to the iron with a force so much greater, in proportion as the iron is less saturated with it.

(2) When three or more simple bodies combine, so as to form one compound, their forces of attraction depend upon similar causes. They may all possess different affinities for each other, or their affinities may be intermediate; and the numbers of the particles of each in the sphere of activity may be different. In cases of ternary and quarternary combination, &c. the conditions are very complicated; and they can only be estimated accurately, by a comparison of the forces exerted by the different substances, considered as to their simplest, or binary attractions for each other. For instances of ternary and quarternary combination, &c. see Div. IV.

(3) When two simple principles, possessed of no affinity for each other, act upon a third simple principle with different forces, two compounds are generally formed; and the simple principle acted upon is divided

according to the masses of the acting bodies, and the different force of their affinities.

Thus when different masses of potash and of soda are mingled and made to act upon a small quantity of muriatic acid, much muriate of potash, and a small quantity of muriate of soda will be formed, though either of the quantities of alkali would have been sufficient for the saturation of the acid, and though the affinity of potash for it is very much greater than that of soda.

(4) All chemical action is connected with change of volume and change of temperature, Div. I. Prop. (6). This circumstance it is necessary to attend to minutely, in judging of the efficacy of combining forces. For as the affinities of substances for each other, are modified by their temperature, Div. I. Prop. (5), it follows, that in all cases of combination, the primary combining forces must be perpetually undergoing alteration, in consequence of the increase or diminution of the temperatures of the substances acted upon.

3. *Of Compound Combination.*

(1) The affinity of one body A, for another B, is not destroyed by its combination with a third C, but only modified; either by condensation or expansion, or by the affinity of B for C. This is an application of the observation mentioned in the last section (3), relating to the combination of more than two bodies. When we reason accurately upon it, we must resolve the affinity of compound bodies for each other, into the affinities of their simple constituent principles; and we must account for the peculiar circumstances of their combination from the modified forces exerted by these affinities. Thus, in the combination of sulphuric acid and ammonia,

five simple affinities may be supposed to exist. 1. That of oxygen for sulphur. 2. That of oxygen for hydrogen. 3. That of sulphur for hydrogen. 4. That of nitrogen for hydrogen, and 5. That of nitrogen for oxygen. The result of the modification of these affinities by each other, is that equilibrium of attracting forces, by which sulphate of ammonia is produced. See Div. I. Prop. 1, and all the observations in the last section.

(2) The modes in which compound affinity is exerted are extremely various. In considering them, it is necessary to attend minutely to the elasticity and cohesion of the different acting principles, and to consider how far these properties are capable of modifying the force of combination.

(3) Amongst the cases of compound combination, some of the most remarkable are those produced by what is called predisposing affinity. Such cases, and various other analogous cases, occur in the formation of the substances mentioned in Div. V.

4. *Simple Decomposition.*

(1) When a simple substance acts upon a compound body, and combines with one or more of its constituents, leaving the other constituent or constituents apparently unaltered, it is said to act by a simple affinity. Thus, charcoal when ignited, and placed in contact with oxyde of copper, is said to combine with its oxygen, in consequence of its simple affinity for it; so that carbonic acid and gaseous oxyde of carbon, are formed, and the copper remains free. Div. I. Prop. (2).

(2) It seldom, however, happens that any perfect decomposition of a compound body is effected by the affinity of a simple substance alone. For, according to

the observation mentioned in Section 2, (3), the body in combination is acted upon by two forces of different degrees of power; and though a new compound is formed, yet the old compound is not perfectly destroyed; and the principle acted upon, is divided between the acting bodies, according to the force of attraction resulting from their primary affinities, and their masses. Thus, when mercury acts upon heated sulphuric acid, two new compounds are formed, oxyde of mercury at its minimum of oxydation, and sulphureous acid; i. e. the oxygen is divided between the sulphur and the mercury, according to their respective attracting forces.

(3) In all cases, in which complete decomposition *appears* to take place from simple affinity, it generally happens that other powers are brought into action; such as a considerable increase or diminution of the force of cohesion in the particles of the body acted upon, which, by altering according to circumstances its powers of remaining in its primary compound, dispose it either to become free, or to combine with the new agent. Div. I. Prop. (5) and (6) and Div. VI. Sec. 2. (4). Thus a complete decomposition of the white oxyde of mercury is produced by the agency of ignited charcoal. But the heat applied in this process acts as much as the charcoal in producing the decomposition: for heat alone is capable of expelling oxygen gas from the white oxyde of mercury.

(4) To determine the elective affinity of two substances for a third, it is necessary to determine in what proportion, as equal masses, they are saturated respectively by equal quantities of the third body. For their affinities are inversely as their saturation. From the constant exertion, however, of the fifth law of attraction, by which the elasticity and force of cohesion of

the particles of different bodies are perpetually varying in different ratios during chemical action, it is almost impossible to determine with perfect accuracy their relative forces of attraction for other bodies. And the tables of elective affinities laid down in various books, must be considered as presenting useful rather than accurate approximations to the true nature of relative affinity.

5. *Complex Decomposition.*

(1) The forces by which a new arrangement of the principles of two or more compound bodies is produced, are usually said to be exerted by complex affinity. Thus, red sulphate of iron, and prussiate of potash are said to be converted into blue prussiate of iron, and sulphate of potash by complex affinity.

(2) The same laws apply to complex decomposition as to simple decomposition, and in all cases the phænomena must be accounted for, from the forces of affinity resulting from the masses of the acting bodies, their primary attractions, and their dispositions towards cohesion, or elasticity. Div. I. the whole of Sect. 5.

(3) The phænomena of compound decomposition have been very little studied; and the instances relating to it, which have been chiefly noticed, are those of *double* affinity, derived from the mutual action of two compound salts.

6. *Of Crystallization.*

When, in consequence of chemical action, solid bodies are slowly produced, or evolved, they generally appear in regular polyhedral forms, i. e. as crystals.

The numerous varieties of crystallization, which immediately depend on variously modified, and complicated forces of attraction, are capable of being explained from different arrangements of six primitive forms. 1. The parallelopidedon in general. 2. The regular tetrahedron. 3. The octahedron with triangular sides. 4. The hexagonal prism. 5. The dodecahedron, bounded by rhombs. 6. The dodecahedron, bounded by isosceles triangles.

PART II.

THE CHEMISTRY OF IMPONDERABLE SUBSTANCES.

DIVISION I.

OF HEAT OR CALORIC.

1. *Introduction.*

A NUMEROUS class of beautiful and important appearances is produced in nature, by agents, which, though very imperfectly known, are yet sufficiently distinguished by their imponderability, and other properties, from the substances considered in the first part of this syllabus.

Heat or caloric, as well as light, electricity, and galvanism, are terms representing the unknown causes of certain effects, which form an interesting part of chemical science, and which without reference to the nature of the powers by which they are produced, may be investigated and arranged as simple collections of facts.

2. *Of the Effects of Heat.*

(1) Heat was considered as the general power of expansion in Part I. Div. I. Its particular agencies, and

the laws by which it is governed, are worthy of a minute examination.

(2) The effects of those actions of heat upon living organs, by which the peculiar sensations of heat and cold are produced, are well known. They are relative, and influenced by the state of the organ.

(3) Bodies increase in volume when heat is added to them, and diminish in volume when it is subtracted from them. The exceptions to this law are very few. Different bodies, and even the same bodies, when differently heated, expand in different ratios, by the additions of equal quantities of heat. In general, gases are more expansible by heat than fluids, and fluids than solids.

(4) The more powerful agencies of heat upon bodies, are often connected with changes in their forms of aggregation. Solids by a certain increase of heat are converted into fluids, and fluids into gases. Also by a subtraction of heat, gases become fluids, and fluids solids.

(5) It was formerly supposed that the absolute weights of bodies were diminished by heat, but some delicate experiments lately made have proved that this opinion is erroneous.

(6) Heat is possessed of most extensive powers in producing chemical combinations, and decompositions. For as it expands different bodies in different ratios, so it likewise diminishes in different ratios the attractions of their particles for each other. See Part I. Div. I. and VI.

3. *Of Radiant Heat.*

(1) Heat, when existing in the radiant state, moves

through space with a velocity almost inconceivable. Like light, it is capable of being reflected, and refracted. And its rays, as would appear from the valuable discoveries of Dr. Herschel, are of different degrees of refrangibility, being for the most part less refrangible than those of light.

(2) When radiant heat falls upon the surface of an opaque body, it is never wholly reflected. Portions of it are absorbed by the body, which become common heat of temperature or free caloric. The powers of absorbing radiant heat, appear to be different in different bodies, and they are, in some measure, connected with their peculiar colours.

(3) The radiant heat emitted from the sun is uniformly combined, or mixed with light; but these agents are capable of being separated to a certain extent by the prism. And, as the experiments of Professor Pictet have proved, the radiation of heat from bodies, on the surface of the earth, is apparently perfectly independent of the presence of light.

4. *Of Temperature, Capacity for Heat, &c.*

(1) The *temperatures* of bodies are said to be high, or low, in proportion as they are capable of communicating, or receiving heat.

(2) And their *capacities for heat*, are considered as great, or small, in proportion as their temperatures are less or more raised by the addition, or diminished by the subtraction of equal quantities of heat.

(3) Bodies, in changing their states of existence, have their capacities uniformly changed. And in this case, they absorb or give out that heat, which, in consequence

of its peculiar relation to the heat of temperature, is called *latent heat*, or caloric of combination.

5. *Of the Communication of Heat.*

(1) When many bodies of different temperatures, and in different forms of aggregation, are brought into contact, they all, after a certain time, whatever change they may have undergone, acquire a common temperature; though their heat is communicated, or received in different manners, and with different degrees of celerity.

(2) *Solids* are the only perfect conductors of heat, for they are the only substances through which heat is communicated, from particle to particle, till the mass or system of bodies becomes of the same temperature.

(3) *Fluid* and *aëriform* substances, strictly speaking, are either perfect or nearly perfect nonconductors of heat. For, according to the important discoveries of Count Rumford, though their particles are capable of receiving heat from other bodies, or of communicating it to them, yet, amongst those particles themselves, all communication of heat appears impossible. And masses of fluids are heated, or cooled, only in consequence of changes in the specific gravities of their particles, by which they are carried in succession to the heating, or cooling body.

6. *Of the Artificial Production of Heat, and of Cold.*

(1) Whenever, during chemical combination, the capacities of bodies are diminished, their temperatures are uniformly increased; and vice versa, when their

capacities are increased, their temperatures are diminished. See Part I. Div. I. Sect. 5.

(2) The chemical changes which are connected with the production of the greatest quantities of radiant heat, and of heat of temperature are, 1. The absorption of oxygen gas by phosphorus, charcoal, hydrogen, iron, &c. 2. The deflagration of combustible bodies by means of nitrate, or oxygenated muriate, of potash. 3. The combination of the alkalies with the acids. 4. The combination of sulphur with certain of the metals.

(3) One of the greatest diminutions of temperature, producible by chemical change, is that which takes place from the action of muriate of lime, or of nitrate of ammonia, or of potash, upon snow.

(4) Heat is capable of being excited by mechanical means. Whenever hard solid bodies are violently struck together, their temperatures are uniformly raised. Likewise an increase of temperature is produced by the friction of solids; and that, as it would appear from the valuable experiments of Count Rumford, under circumstances, when these substances are incapable of undergoing either a chemical change, or a change of capacity.

7. *Theories concerning the Nature of Heat.*

(1) Two theories concerning the nature of heat have been most prevalent amongst philosophers. 1. It has been supposed to be a peculiar ethereal fluid. 2. It has been conjectured to be a property of common matter; a specific motion of the particles of bodies.

(2) The arguments in favour of the first of these theories, have been chiefly deduced from the phænomena

of latent heat, of radiant heat, and of change of capacity; whilst the last of them has been supported by experiments on the excitation of heat by friction, in cases in which there existed no perceptible source, from which, considered as a substance, it could possibly be derived.

(3) The late experiments of Dr. Herschel have demonstrated, that radiant heat must be constituted by the motions of a peculiar substance. And these motions may be conceived to be either rectilinear projections, or undulations.

(4) It has been lately supposed that they are undulations. And on this theory it has been assumed, 1. That an elastic ethereal medium exists in space. 2. That this medium is diffused through the pores of different ponderable substances, in different states of density. 3. That radiant heat is constituted by particular undulations of it, when in a free state. 4. That sensible heat is occasioned by particular undulations of it, in its states of diffusion through the pores of ponderable substances. 5. That certain peculiar vibratory motions of the particles of ponderable substances are capable of producing the undulations in the ethereal medium which constitute heat. 6. And reciprocally that those undulatory motions of the ethereal medium are capable of producing peculiar vibrations of the particles of ponderable substances.

(5) These propositions are evidently countenanced by the experiments of Count Rumford and Professor Pictet, on the heat produced by friction. They are rendered more conclusive by the analogy between the laws of the motions of radiant heat, and those of sound. And they, in some measure, reconcile the two different theories.

8. *Of the Instruments used in Experiments upon Heat.*

(1) Thermometers and pyrometers are instruments for measuring the temperatures of bodies.

(2) *Thermometers* are used for ascertaining degrees of temperature, which are generally not much higher or lower than those of the atmosphere. They are formed on the principle of the expansion of bodies by heat; and such substances are employed in them, as expand most uniformly by successive equal increments of heat. The common thermometers with mercury and alcohol are well known. As thermometers in all cases act only as substances giving, or receiving heat, the quantity of fluid they contain should in all cases be very small: for, in proportion as it is small, so in proportion will the thermometrical expansions or contractions more accurately denote the real temperature of the body experimented upon.

(3) *Pyrometers* are employed for measuring very high temperatures. They are usually formed of baked clay, a substance which, differing from almost all other bodies, contracts in volume by heat. The contractions of the pyrometer are considered as the measure of its temperature; and they are apparently great, in proportion as the temperatures to which it is exposed are high.

(4) The *calorimeter* is an instrument that has been used for the purpose of ascertaining the relative capacity of bodies for heat. It is founded upon the principle, that ice, during its conversion into water, absorbs uniformly the same quantities of heat: and it is composed of tin vessel filled with ice, and surrounded by ice. In this vessel, the substance experimented upon is placed; and its capacity is supposed to be directly as the

quantity of ice, which, when of a given temperature, it is capable of converting into water.

9. *Agency of Heat in Nature.*

Upon the various operations of the radiant heat of the sun absorbed, or rendered sensible in bodies, almost all the phænomena which are the subjects of *meteorological science* depend: evaporation, the solution of water in air, and its precipitation from the atmosphere, the existence of rivers, the fluidity and solidification of water, &c.

By this agent likewise are most of the new combinations, and decompositions, of substances produced, by which they are rendered capable of organization, and of becoming parts of living beings.

From the chemical generation of heat in animal bodies, during respiration, and other changes, the organs are preserved in those states of temperature, which are necessary to the exertion of the vital functions.

In short, the agency of heat in nature is almost universal; and it either primarily occasions, or materially influences, all the different changes that take place upon our globe.

DIVISION II.

OF LIGHT.

1. *Effects of Light.*

Light is known to us as the cause of a numerous class of sensations. It is possessed of powerful chemical agencies. One of its common effects is the expulsion of oxygen in the state of gas from bodies with which it is loosely combined. Thus, it decomposes the nitric and oxygenated muriatic acids, and blackens the salts containing oxyde of silver.

2. *Laws of Light.*

Light moves through space at the rate of 200,000 miles in a second. It is reflected from certain opaque bodies. In passing through transparent bodies it is refracted; and its rays are of different degrees of refrangibility. They are separated when passed through the prism, into seven species, red, orange, yellow, green, blue, indigo, violet. The laws of light in their relation to vision, constitute the subject of *optics.*

3. *Of the artificial Production of Light.*

(1) Light is produced during a number of chemical operations. 1. By the union of oxygen gas, and of oxygen in particular states of combination, with certain combustible bodies. 2. By the action of the mineral acids on the fixed alkaline substances. 3. By the combination of sulphur with the metals. 4. By the action of sulphuric acid upon the moistened oxygenated muriates.

(2) All solid, and fluid substances become luminous, when heated to a temperature corresponding to about 850°.

(3) Certain bodies, called solar phosphori, after having been exposed to light, exhibit a luminous appearance in the dark; and this appearance is rendered more vivid by increase of their temperature. By

a high degree of heat indeed, it is at length destroyed; but it is capable of being restored by a second exposure to light.

(4) Light is produced during the collision of different bodies, but this phænomenon is probably in general either dependent on combustion, or on the excitation of electricity.

4. *Opinions concerning the Nature of Light.*

(1) Two opinions have been formed concerning the nature of light, in its visible state. 1. It has been supposed to be produced by the rectilinear rapid motions of the minute particles of a peculiar substance. 2. It has been considered as the undulatory motion of an elastic ethereal medium extended through space.

(2) The first of these opinions has been for a long while most prevalent; and, indeed, even now, it is generally adopted. The last of them, however, has been lately supported by some important arguments deduced by Dr. Young, from the analogy between the laws of known undulatory motions, and those of light.

(3) Though the phænomena of the reflection and refraction of light are very analogous to those of radiant heat; and though these bodies are usually present at the same time, yet the distinctness between their physical, as well as their chemical powers of action is sufficient to induce us to believe that they are perfectly different agents. The heat and light in the solar spectrum produce perfectly different effects: for if muriate of silver be exposed to the differently refracted rays, it is found that the invisible heat-making rays produce no effect upon it; its colour is altered by the

violet rays in about $\frac{1}{80}$ part of the time in which it is changed by the red; and, what is very curious, it is likewise acted upon in the space beyond the violet rays. This circumstance has been noticed by Messrs. Ritter and Böckman, and by Dr. Wollaston. It would appear from it, that invisible rays exist, which, though possessed of chemical agencies, and of the highest degree of refrangibility, are, nevertheless, incapable of producing heat.

5. *Of the Photometer.*

The photometer is an instrument for measuring the intensity of light. Photometers have been generally constructed on the supposition that the intensity of light is proportional to its power of heating bodies, or to its power of producing chemical changes in them. This supposition is, however, contradicted by all the late experiments on the solar spectrum: and, in consequence, the ingenious instruments, to the invention of which it has given rise, are rendered useless, as to their primary purpose.

For measuring the relative intensities of the light emitted by two different bodies in combustion, a very simple and useful photometer has been invented by Count Rumford; and it is founded upon the principle, that the power of a burning body to illumine any defined space, is directly as the intensity of the light, and inversely as the squares of the distance.

6. *Agencies of Light in Nature.*

(1) The action of solar light upon living vegetables, is in most cases connected with the production of

oxygen gas; a circumstance, probably intimately related to the uniformity of the constitution of our atmosphere; from which oxygen is constantly absorbed, by the respiration of animals, combustion, and other causes.

(2) Light is possessed of a decided influence in modifying many natural phænomena. The crystallization of salts is materially affected by its agency. It is capable of altering most of the colours of bodies. And it is perpetually producing numerous decompositions, and new combinations upon every part of the surface of the globe.

(3) Light is possessed of great powers of action upon organized beings. The colours of the leaves of vegetables, and of their flowers, are almost wholly dependent upon it: and vegetables are incapable of existing for any great length of time, when deprived of its benign influence.

DIVISION III.

OF THE ELECTRIC INFLUENCE.

1. *Effects of Electricity.*

(1) Electricity in its different states of accumulation produces different effects. In general, its presence is denoted in substances, by their powers of attracting, or repelling, under different circumstances, light bodies. Electricity often appears in the form of light; and, in this state, it is capable of igniting bodies, and of inflaming such of them as are combustible. It occasions vivid sensations, called electrical shocks, in passing

through living bodies. It is sensible to the organs of taste and smell.

(2) Electricity is possessed of very powerful chemical agencies. It is capable of producing a number of combinations, and of decompositions; and some of its effects are analogous to those produced by very intense degrees of heat.

(3) Nitric acid is formed from oxygen gas and nitrogen gas, by means of electricity. Water is converted by it into oxygen and hydrogen. And ammonia is decomposed into nitrogen and hydrogen.

2. *Of the Conductors and Nonconductors of Electricity, and of their different States with regard to Electricity.*

Amongst the conductors of electricity are the metals, charcoal, the fluid acids, water, and moist animal and vegetable substances. Amongst the nonconductors are glass, resin, wax, sulphur, phosphorus, oils, dry gases, and all the solid compounds containing earths only, or alkaline substances.

Bodies when actively electrified, are either in the positive, or the negative state. When in the positive state, they are supposed, in the common theory, to contain more than their natural quantity of electrical influence, and when in the negative state less.

The processes by which the equilibrium of electricity in bodies is destroyed and restored, the effects connected with these processes, and their relations to the general properties of matter, are capable of being explained upon mathematical principles, and they are considered as constituting the *general science of electricity*.

3. *Of the Excitation of Electricity.*

(1) One of the most simple modes of exciting electricity, is by the friction of two nonconductors, or of a nonconductor and a conductor.

(2) When a glass cylinder, or a circular plate of glass, mounted upon a nonconducting stand, is made to revolve upon its axis, so as to rub against cushions of leather covered with an amalgam of mercury and zinc, the electrical equilibrium is destroyed. The cushions, and the conductors in contact with them, become negatively electrified; and a conductor placed near any part of the glass, which is not in contact with the cushion, becomes positively electrified.

(3) When globes, or cakes of resin, are used in the same manner, electricity is likewise excited; but in this case, the cushions and their conductors become positively, and the other conductors or the prime conductors negatively, electrified.

(4) Electricity is excited in certain nonconducting bodies, merely by changes in their states of temperature. The topaz of Brazil, and the tourmaline, become electrical whenever they are gently heated; and sulphur and sealing wax when cooled after having been melted, are found strongly electrified.

(5) Indeed, whenever bodies change their forms of aggregation, whether from the agency of heat, or other causes, there is every reason to believe, that their states, with regard to electricity, are changed. Water, during its conversion into vapour, appears to absorb much electricity from the bodies in contact with it, so that they become negatively electrified. And during the condensation of aqueous vapour, electricity is evolved.

(6) Electricity is capable of being excited by the

action of different conducting substances on each other; but the modes of this excitation, and its general connection with chemical changes, constitute a science which has been hitherto distinguished from common electricity, by the name of *galvanism*, and which will be immediately considered.

4. *Theories concerning Electricity.*

Electricity has been supposed to depend upon the agencies of two particular substances, which have been called, from the modes of their excitation, vitreous, and resinous electricity. It has likewise been supposed to owe its existence to the agencies of one specific body. The last of these theories has been lately generally adopted by the greater number of philosophers. It has been elucidated by the investigations of Dr. Franklin, Mr. Æpinus, and Mr. Cavendish: and it is adequate to the solution of all the phænomena.

In this theory, the different electrical appearances are accounted for from the following suppositions.

1. The particles of the electrical fluid repel each other with a force diminishing as their distances increase. 2. They attract particles in all other bodies, with forces increasing as the distances decrease; and the attraction is mutual. 3. They move through the pores of conductors with perfect ease, and with great velocity; but they either move with great difficulty, or they are altogether incapable of moving through the pores of nonconductors. 4. They are capable of being transferred from the pores of one body to those of other bodies; so as to exist in states of accumulation, and of deficiency.

5. *Of Electrical Instruments.*

(1) The Leyden phial is a glass vessel, partially coated on its internal and external surfaces with tinfoil, or other conducting substances. It is charged by electrifying one of its surfaces positively, at the same time that the other surface is connected with the ground, by which it is enabled to become negatively electrified. It is discharged by connecting, by means of a conductor, its positively and negatively electrified surfaces; when the equilibrium is restored.

(2) The electrophorus is composed of a nonconducting plate, which is generally of resin, attached to the upper surface of a conductor, and of a conducting plate having a nonconducting handle. After the nonconducting plate has been once excited, its under surface being connected with the ground; the conducting plate, as often as it is laid upon it and brought in contact for a moment with another conductor, will so often be capable of furnishing a spark, after having been removed from it, by the nonconducting handle.

(3) Bennet's electrometer is composed of two gold leaves, attached to a conducting plate, and enclosed in a tube of glass. It is used for ascertaining the presence of small quantities of electricity in bodies; which are denoted by the separation of the leaves.

(4) The condenser, the doubler, and the multiplier, are instruments generally employed for the purpose of rendering sensible, by means of the electrometer, quantities of electricity immediately imperceptible.

6. *Agency of Electricity in Nature.*

Electricity appears to act an important part in most of the natural operations that take place upon the surface of our globe, and in the atmosphere. Lightning, thunder, the aurora borealis, and many other phænomena of meteorology, are caused immediately by this powerful agent.

By the extensive action of electricity various changes in living and dead matter are perpetually produced. It occasions, or accelerates, in many instances, the phænomena of fermentation, of putrefaction, and of the general decomposition of organized compounds.

DIVISION IV.

OF GALVANISM.

1. *Of the Nature of Galvanism.*

Galvanism relates to the peculiar chemical and electrical phænomena, which are occasioned by the contact of different conductors of electricity.

This science, though yet in its infancy, is composed of a number of important facts. Its relations are very extensive, and it furnishes powerful and novel instruments of chemical and physiological investigation.

2. *Of the Construction of the least complicated Galvanic Arrangements, i. e. Simple Circles.*

(1) The conductors of electricity, which by their mutual agencies are capable of producing galvanic appearances may be divided into two classes. 1. Perfect conductors, which are either metals or charcoal. 2. Imperfect conductors, which are either oxydated fluids, or substances containing such fluids.

(2) For the composition of a simple galvanic circle, at least two conductors of one class, and one of another class are required. And they must be so disposed that the conductors of the one class may be in contact with each other in one or more points, at the same time that they are connected in other distinct points with the conductor of the other class. Thus, if plates of zinc and gold be made to touch each other in one point, and be connected together in other points, by a portion of common water, or diluted muriatic acid, a simple galvanic circle is formed. A simple galvanic circle is likewise formed when separate portions of water, and solution of hydrogenated sulphuret of potash are connected together in one point, and brought in contact in other points with a piece of silver.

(3) Every arrangement, however, of two conductors of one class with one of the other, is not an acting galvanic circle. For the production of galvanic effects, it is necessary, that the fluid part or parts of the circle should be capable of acting chemically upon the solid part or parts of the circle. The most powerful circles are those in which two different chemical actions are exerted in different parts of the arrangement; and in every acting circle there is at least one point, in which oxydation, or some other chemical change is taking place.

The following tables, in which some different simple circles are arranged in the order of their powers, will show how intimately primary chemical changes are connected with the production of galvanism.

TABLE OF SOME GALVANIC CIRCLES,

COMPOSED OF TWO PERFECT CONDUCTORS AND ONE IMPERFECT CONDUCTOR.

More oxydable substances.	Less oxydable substances.	Oxydating fluids.
Zinc...	With gold, charcoal, silver, copper, tin, iron, mercury.	Solutions of nitric acid in water, of muriatic acid and sulphuric acid, &c. Water holding in solution oxygen, atmospheric air, &c.
Iron...	—— gold, charcoal, silver, copper, tin.	
Tin ...	—— gold, silver, charcoal.	
Lead ..	—— gold, silver.	Solution of nitrate of silver and mercury. Nitric acid, acetous acid.
Copper.	—— gold, silver.	
Silver..	—— gold.	Nitric acid.

TABLE OF SOME GALVANIC CIRCLES,

COMPOSED OF TWO IMPERFECT CONDUCTORS AND ONE PERFECT CONDUCTOR.

Perfect Conductors.	Imperfect Conductors.	Imperfect Conductors.
Charcoal.	Solutions of hydrogenated alkaline sulphurets capable of acting on the first three metals, but not on the last three.	Solutions of nitrous acid, oxygenated muriatic acid, &c. capable of acting on all the metals.
Copper.		
Silver..		
Lead ..		
Tin ...		
Iron.		
Zinc...		

3. *Of the Agencies of Single Galvanic Circles.*

The galvanic influence is manifested in single circles, either by its power of acting upon living animal organs, or by its chemical agencies.

(1) When the tongue is made part of a simple galvanic circle, an acid taste is perceived, and when the eye is connected with it, a flash of light is produced.

(2) When the galvanic agency is made to act on a muscle, and the nerve attached to it, which have just been separated from the body of a living animal, muscular contractions are uniformly produced.

(3) In all the single galvanic circles, the primary chemical actions are increased, and to a certain extent modified. Thus, when zinc, which oxydates slowly when exposed to the atmosphere in contact with water, is made to form a galvanic circle with that fluid and silver, it oxydates rapidly; and an alkali appears to be formed in the water at its points of contact with the silver. Likewise, when iron and silver form a circle with diluted muriatic acid, the action of the acid upon the iron is increased; and hydrogen gas is not only evolved from the water in contact with the iron, but likewise from that in contact with the silver.

4. *Of Compound Galvanic Circles or Galvanic Batteries.*

(1) Galvanic batteries are composed by series of the substances which form simple circles; and these substances are arranged in such a manner, that the conductors of the same class in every series are in contact with each other in one point or more, at the same time that they are respectively connected with different conductors of the other class, so that a regular alternation is observed; the order being, conductor of the one class, conductor of the one class, conductor of the other class, and so on. Thus, if plates of zinc and of silver, and

pieces of cloth of the size of the plates, moistened in water, be arranged in the order of zinc, silver, cloth; zinc, silver, cloth, and so on, till twenty series are connected together, the galvanic battery of Volta will be formed. Likewise a galvanic battery will be formed if pieces of tin, iron, or charcoal, be introduced into glasses filled some with water, and some with nitric acid, and connected in pairs by siphons, in the order of metal or charcoal, acid, water; metal or charcoal, acid, water, and so on, till twenty series are constructed.

(2) The substances most active in the simple circles are likewise most active in the compound circles. And in all cases, the relative quantities of galvanic power exhibited by equal numbers of different series, are in some measure proportional to the intensity of the peculiar primary chemical agencies, exerted by the different conductors composing them, on each other. The tables of the simple circles will indicate, with the necessary changes of arrangement, the powers of such compound circles as are composed of similar parts.

5. *Of the Agencies of Galvanic Batteries.*

(1) The galvanic influence in its accumulated state in compound circles, produces very singular physical and chemical effects, and exhibits many of the appearances of common electricity.

(2) It produces shocks, when made to act upon the human body, which are very analogous to those occasioned by the electrical battery.

(3) It passes through air and certain other nonconductors in the form of sparks; and in this state it is capable of burning charcoal, and metallic bodies, when they are in contact with the atmosphere; and like-

wise of inflaming mixtures of oxygen gas and hydrogen gas.

(4) It affects the electrometer; and is capable of communicating weak charges to the condenser, and Leyden phial.

(5) In passing through common water from perfect conductors, it effects chemical changes very analogous to those taking place in the different primary series, in which it was excited; producing in its positive state, oxygen and an acid; and in its negative state, hydrogen and an alkali.

6. *General Observations on Galvanic Circles.*

(1) Provided those points of contact, in both the simple and compound galvanic circles, in which the chemical agencies of the different conductors on each other are more particularly exerted, remain permanent, the parts of the series, which do not immediately act chemically on each other, may be connected together by means of conductors of their own class, without any other change in the agencies of the circle than a diminution of their intensity. This diminution, with regard to perfect conductors, is barely perceptible; though in the case of imperfect conductors it is evidently, in some measure, correspondent to the increase of the length, or what is apparently equivalent, the diminution of the surface of the chain that they compose.

(2) The agency of the galvanic influence which occasions chemical changes in water, and communicates shocks to the living body, is probably, in some measure, distinct from that agency which produces sparks, and the combustion of bodies. The one appears, all other circumstances being similar, to have

little relation to surface in compound circles; but to be great in some unknown proportion as the series are numerous. The intensity of the other seems to be as much connected with the extension of the surfaces of the series, as with their number.

(3) A measure of the intensity of that agency in galvanic batteries, which produces chemical changes in water, may be derived from the quantity of gas it is capable of evolving in a given time; or from the length of the fluid chain through which it can be transmitted. The comparative forces of different batteries may be determined by connecting them in an order different from that of the regular alternation, so as to produce a certain annihilation of power; for in all instances when the most oxydable part of one series is connected, by means of a fluid, with the analogous part of another equal series, the galvanic powers of both are destroyed.

7. *Theories concerning Galvanism.*

(1) The obscurity of the galvanic facts which were first noticed, and their apparent insulation, gave rise at an early period of the science, to many different theories concerning galvanism. It was supposed, 1. That it was a peculiar ethereal fluid. 2. That it depended upon hydrogen, disengaged during the decomposition of water by metals. 3. That it was the electrical fluid existing in a peculiar state.

(2) Since the discovery of the agencies of the accumulated galvanic influence, the last of these suppositions has been adopted by the greater number of those philosophers who have studied the subject with accuracy. Galvanism is now generally believed to be electricity; and the chief difference that prevails in theory, is with

respect to the manner in which this electricity is excited.

(3) M. Volta has supposed, that an electrical current is always produced by the mere contact of certain different conductors of electricity. But many of the British philosophers have denied this position; accounting for galvanism from the destruction of the equilibrium of electricity in galvanic circles, in consequence of the chemical agencies of the different bodies composing them.

8. *Of the Appearance of Galvanism in Animal Organs.*

(1) The well known facts relating to the torpedo, electrical eel, &c. prove that galvanic electricity is capable of being excited by the agencies of living organs. These facts, compared with the phænomena of the production of muscular contractions by galvanism, lead to interesting inquiries concerning the relation of this influence to living action. The general connection of electricity with physiology and with chemistry, which is at present involved in obscurity, is probably capable of experimental elucidation; and the knowledge of it would evidently lead to novel views of the philosophy of the imponderable substances.

PART III.

THE CHEMISTRY OF THE ARTS.

DVISION II.

OF AGRICULTURE.

1. *Of the Growth of Vegetables.*

(1) Vegetables derive their component principles, which have been described in Part I. Div.V. and which are, for the most part, hydrogen, carbon, oxygen, and nitrogen, either from the atmosphere by which they are surrounded, or from the soil in which they grow.

(2) They are capable of being produced from seeds; and the process of vegetation appears to depend upon the perpetual assimilation of various substances to the organs of the plant, in consequence of the exertion of their living powers, and of their chemical affinities.

2. *Of the Influence of the Atmosphere on Vegetation.*

(1) The atmosphere is chiefly composed of about 78 parts of nitrogen gas, 21 parts of oxygen gas, and 1 part of carbonic acid gas. But these aëriform fluids always

hold in solution a considerable quantity of water; and at the surface of the earth, many vapours, and different solid and fluid bodies, are perpetually suspended in them.

(2) Plants are incapable of vegetating when deprived of air. The changes they effect in the atmosphere are intimately connected with the agencies of light: for, though they evolve oxygen gas from their leaves, when exposed to the direct rays of the sun; yet, in the shade, and in darkness, they seem to absorb this principle; and at the same time to give out carbonic acid.

(3) The vegetation of plants is much assisted by putrid vapours floating in the atmosphere. Air saturated with moisture is much more favourable to the process than dry air. Portions of the carbonic acid in the atmosphere, are perpetually absorbed in the light, by the fluids in the vessels of plants; and from this substance is probably derived much of the carbon they contain.

(4) Oxygen gas, or oxygen in a state of loose combination, is absolutely essential to the germination of seeds. By means of it, the mucilage they contain, is probably converted into sugar; which appears to be the first food of the plant. Oxygenated muriatic acid is a substance very active in producing the evolution of germs.

3. *Of Soils.*

(1) Alumine, silex, and carbonate of lime, mingled or combined in different quantities, and in different states of cohesion, constitute the greater portion of soils. These substances appear, however, to contribute very little immediately to the nourishment of plants;

but, from the peculiar form of their mixture, they enable them to grow, so as to be exposed in the best possible manner to the influence of the atmosphere; and, at the same time, they supply them in a proper manner with water and other fluid substances, which are perpetually deposited or formed on the surface of the earth, and which are essential to their existence.

(2) Almost all soils contain certain portions of decomposing vegetable matter, which, when acted upon by water, and the oxygen of the atmosphere, produce compounds, capable of being absorbed by the organs of plants, so as to form part of their nourishment. Likewise, soils in general contain oxyde of iron, and various neutral salts: and these compounds, under certain circumstances, appear to accelerate vegetation; either by their agency on the living powers of plants, or by producing such changes in other substances, as enable them to become the food of plants.

(3) As different vegetables are nourished by different food, and as they require to be supplied with food in various manners, so they vegetate to the greatest advantage in different soils.

The nature of the soils, however, which different vegetables demand, must, in some measure depend upon the state of the surrounding atmosphere.

In countries where the air is dry, and where very little rain falls, the soil should be extremely retentive of moisture; and in this case, it should contain a very considerable proportion of aluminous earth.

Sandy, and silicious soils are the least tenacious and retentive of water; and of course they are extremely pernicious to vegetation in dry climates.

(4) The constituent principles of soils may be easily discovered by chemical analysis; and their relative

powers of absorbing and retaining moisture by means of the hygrometer.

4. *Of the Action of Water on Vegetables.*

(1) Water is absolutely essential to the life of vegetables. It is absorbed by them in great quantities from the atmosphere, and from the soil in which they grow. It almost wholly composes the sap contained in their vessels, and contributes materially to their nourishment.

(2) There is every reason to believe that the hydrogen, which in different compounds forms so considerable a portion of the organized matter of plants, is obtained in a great measure, from the decomposition of water; and the oxygen, which they evolve when exposed to the solar light, is probably derived from the same source.

(3) The water absorbed by plants, not only holds in solution certain portions of carbonic acid, and of atmospheric air, but likewise often mucilage, gelatine, and other substances, the products of spontaneous vegetable and animal decomposition, which are in a state eminently adapted to become parts of living vegetables.

5. *Of the Influence of Heat and Light on Vegetables.*

(1) A certain degree of heat is absolutely essential to the preservation of the life of plants. At temperatures much below the freezing point, the living action of their vessels is destroyed, and the fluids that they contain are frozen.

(2) The greater number of plants grow and evolve

new organs only during the spring and summer months. After they have produced seeds, their excitability is exhausted by the heats of autumn: and during the cold of winter those decompositions, and new combinations, which are connected with the process of vegetation, cease altogether.

(3) Plants when deprived of light soon become pale coloured and unhealthy, the fluids accumulate in their vessels in more than their just proportions, and they are rendered incapable of producing seeds.

(4) There is every reason to believe, that the presence of light is connected with the decomposition of water and of carbonic acid by plants; and so far, it may contribute to the formation of their solid parts. The production of resin, gum, and tannin, in the epidermis and cortical layers of plants, appears to be materially influenced by this agent.

6. *Of Manures.*

(1) Manures are substances used for accelerating the process of vegetation; and they are either mingled with the soil, or strewed over it.

(2) The most useful manures are those which immediately supply nourishment to the plant. Amongst them, are vegetable, and animal matters, that have undergone putrefaction; dung of different kinds; and various substances given out as excrementitious by animals, which contain carbon, hydrogen, and oxygen, in such combinations as readily enable them, under certain circumstances, to be absorbed by plants, and to be combined with their organs.

(3) The manures of secondary use are such, as without supplying immediate nourishment to plants, hasten

their growth; either by rendering their common food more nutritive in consequence of their chemical agencies upon it: or by stimulating the vegetable organs, so as to enable them to act with greater energy upon this food.

Various preparations of lime, gypsum, and different neutral salts, are considered for the most part, as manures of secondary importance: and in consequence, these substances are employed with advantage in such soils as contain much slowly decomposing vegetable matter.

7. *Of the Cultivation of Lands.*

(1) To understand the mode of procuring from a given quantity of land, the greatest possible proportion of such vegetables as are necessary for human food, the food of animals, or for other purposes connected with human wants, is the great desideratum in agriculture.

To obtain this desideratum, it is necessary to study with accuracy the nature of the different soils which are the subjects of agricultural operations; to discover by experiments what vegetable substances they are best calculated to support; and to determine how far their nature may be modified, by successions of crops of different vegetables, or improved, by fallowing, liming, or other analogous processes.

(2) The knowledge of the proper mode of cultivating the earth, is connected with almost all the physical sciences; and the phænomena of vegetation, constitute a great part of what is known concerning the philosophy of living nature. Agriculture, as it has been hitherto practised, is an art very little assisted by theory. From the modern discoveries in chemistry, there is every reason to believe, that it is eminently susceptible of

improvement; and we may venture to hope, that inquiries concerning it will become generally interesting, as they are intimately related to the well being of society.

DIVISION II.

OF TANNING.

1. *Of the Nature of Tanning.*

(1) Tanning is that art by which the skins of animals are impregnated with tannin or the tanning principle, in such a manner as to be rendered tenacious, durable, and impermeable to water.

(2) The processes by which skins are tanned, are extremely various in different countries, and even in different provinces of the same country. When, however, the theory of the art is examined, they may be easily generalised, and considered under two heads. 1. The depilation and preparation of skin for tanning. 2. The impregnation of prepared skin with the tanning principle.

2. *Processes of Tanning.*

(1) **Depilation and preparation of skin.** The depilation of skins is usually effected; either by an incipient putrefaction, or by the action of lime water on the epidermis. After depilation, they are prepared for combination with tannin, in one case by the action of a very diluted solution of sulphuric acid upon them; and in the other by the agency of certain weak alkaline

lixivia, formed by the action of water upon certain animal excrements.

(2) IMPREGNATION OF SKIN WITH TANNIN. The solutions employed for impregnating skins with tannin, are made by the infusion of various barks, and other substances in water. They are used of different degrees of strength; and in common operations, the skins are first exposed to the action of weak solutions, and are afterwards introduced into stronger ones. The time required for tanning different skins is very different, and depends in a great measure upon the quantities of tannin dissolved in the solutions employed.

3. *Of the Composition and Texture of Skin.*

(1) The skin, as taken from the animal by mechanical means, is evidently composed of three distinct membranes. 1. The cuticle or epidermis. 2. The mucous membrane. 3. The cutis or true skin.

(2) The *epidermis* is a membrane possessed of very little organization. It is formed by the union of a number of small semitransparent plates. It is composed chiefly of albumen combined with a little gelatine, and phosphate of lime. It is very little acted upon by water, but is extremely soluble in fixed alkaline solutions. See Part I. Div. IV. Sect. 4.

(3) The *mucous membrane*, which is situated immediately under the epidermis, upon the true skin, is composed chiefly of nervous papillæ, and of a soft gelatinous substance, which is supposed to contain the matter that gives to the skin its peculiar colour.

(4) The *cutis* or true skin, which forms by far the greatest and most important part of the skin, is a thick, firm, elastic substance, constituted by a number of fibres

interwoven with each other and intersected by small blood vessels and nerves. It is composed of gelatine combined with a small portion of fibrine, albumen, and phosphate of lime. It is acted upon by boiling water, and its gelatine is dissolved. The aqueous solution of this gelatine by evaporation forms glue. See Part I. Div. V. Sect. 5.

4. *Of Barks and other Substances employed for forming Tanning Lixivia.*

(1) In Britain, the oak bark is generally used for producing the tanning lixivium. It is stripped from the trees in spring, and is rendered dry by exposure to light and air. The tanning lixivium is formed by introducing it in small fragments, or in coarse powder into cold water, when its soluble parts are slowly dissolved.

(2) The barks of the willow, the hazel, the chesnut, the ash, the poplar, and of many other trees, are equally proper with that of the oak, for forming tanning lixivia; but in general they contain a smaller quantity of the tanning principle. In all barks, the epidermis contains the least proportion of tannin. And even in the cortical layers this substance is most abundant, in proportion as they are nearer to the woody fibre.

(3) Besides tannin, the aqueous infusions of barks generally contain gallic acid, mucilage, and colouring matters. And the different proportions of these substances may be known from a chemical analysis. The quantity of tannin in any infusion may be discovered by means of solution of glue, with the gelatine of which it forms an insoluble precipitate: and after the separation of the tannin, the presence of the gallic acid is

denoted, by its striking agency upon solution of red sulphate of iron.

(4) Many substances have been used in tanning, which contain a much larger proportion of tanning principle than any of the common barks. Amongst them are sumach, Aleppo galls, and common galls.

5. *Of the Theory of Tanning.*

(1) The depilation of skins by lime water, appears to be simply owing to the action of the lime upon the albumen of the epidermis, by which, its texture is destroyed in such a manner, that the hairs can easily be separated from the mucous membrane and the skin.

(2) The chief use of the preparatory weak alkaline lixivium is probably to free the skin from fat, oil, and other matters insoluble in water, and incapable of combining with tannin; and these purposes are effected by means of its free alkali, which forms with such matters in general soluble soaps.

(3) The prepared skin is tanned in the infusions of bark, probably, in consequence of the combination of its gelatine and albumen in their organized form with the tanning principle, in such a manner, and so slowly, that the primitive shape and fibrous texture of the skin are preserved, at the same time that it becomes insoluble in water, and gains a different appearance and new strength. Whether the gallic acid, and colouring matter of bark, are of any use in tanning, has not been yet ascertained. The gallic acid, by its action upon water, increases the solubility of tannin; but it is not apparently altered during the conversion of skin into leather.

6. *Of Improvements which may probably be made in the Processes of Tanning.*

(1) The lixivia of bark employed in this country are in general extremely weak, and in consequence the operation of tanning is performed only in a great length of time. Much expense and labour may probably be saved by the use of stronger lixivia, according to the method adopted in France by M. Seguin. These lixivia, however, as in the common practice, should contain different quantities of tannin; and that in which the skin is last immersed, for the completion of the process, should be uniformly the strongest.

(2) The tanning principle may be easily obtained in a solid form, and nearly in a pure state, by evaporation of the strongest infusions of barks: and in such a form it might be easily made an article of commerce, so as to be imported into Europe from those newly discovered countries in which forests abound, and in which they impede so materially the progress of cultivation.

(3) From some experiments lately made, it is probable that certain vegetables which do not originally give out tannin to water, may be made to evolve, or produce that principle in its soluble state, by particular chemical operations. This discovery, if it be confirmed by new facts, will admit of very important and extensive applications.

DIVISION III.

OF BLEACHING.

1. *Of the Bleaching of Wool, and Silk.*

(1) Wool is generally bleached by the action of weak ammoniacal solutions, and of sulphureous acid. It is first immersed in the ammoniacal solution, which combines with the oil, or grease diffused over its surface. It is then washed, and exposed to the agency of sulphureous acid, which is sometimes employed in the liquid, but oftener in the aëriform state. By means of this substance the colouring matters combined with it are speedily destroyed, or rendered easily soluble in water.

(2) Silk, in its native state, is rendered white by immersion in a weak solution of soda, and a subsequent exposure to the action of sulphureous acid dissolved in water. The theory of the process is very little known, but it appears to be the same as that of the process for bleaching wool.

2. *Of the Bleaching of Linen and Cotton.*

(1) Linen and cotton were formerly bleached by a long exposure to the action of light and air; but the modern discoveries in chemistry have given rise to new methods, which are now almost universally adopted.

(2) Oxygenated muriatic acid destroys the greater number of vegetable colours. It was first applied to the process of bleaching, by M. Berthollet, and is now in

common use. It is prepared in manufactories by the action of sulphuric acid upon a mixture of muriate of soda and black oxyde of manganese; and it is made to act upon the substances to be bleached, in the form of a weak aqueous solution.

(3) The oxygenated muriates of potash, lime, &c. are indeed often preferred to the pure oxygenated muriatic acid; which sometimes alters the texture of the cloth and diminishes its strength. They are prepared by passing oxygenated muriatic acid into solution of caustic potash, or of lime, and they are employed in a very diluted state.

(4) The solution of hydrogenated sulphuret of lime has been applied with considerable advantage, to certain of the processes of bleaching, by Mr. Higgins; and it may be used in common with alkaline solutions for preparing linen for the action of oxygenated substances.

(5) A method of bleaching, by means of steam, has been lately proposed by M. Chaptal. It consists in the application of the vapour disengaged from a heated fixed alkaline lixivium to the substances to be acted upon; and it is said to be in many respects superior to the common process.

3. *Of the Theory of Bleaching, by Oxygenated Muriatic Acid.*

(1) The colouring matters destroyed in bleaching appear to be chiefly oxydes, with bases compounded of carbon and hydrogen, insoluble in water; and it is probable that they are converted by the action of the oxygenated muriatic acid into carbonic acid and water.

(2) But the theory of the different processes of bleaching is as yet very imperfectly known. And the small-

ness of the quantity of colouring matters, and their susceptibilities of change render it very difficult to make them the subjects of accurate experiments.

DIVISION IV.

OF DYEING.

1. *Of the Nature of Dyeing.*

Dyeing is the art of impregnating cloths, stuffs, and other substances manufactured from vegetable, and animal products, with different permanent colouring matters.

The processes relating to this art are purely chemical, and they depend, in a great measure, upon the exertion of particular affinities by the substances to be dyed, and the different colouring matters.

2. *Of the Substances usually Dyed.*

(1) The substances usually dyed are articles of clothing, composed either of wool, silk, cotton or linen.

(2) Wool and silk have a much stronger affinity for the colouring matters employed in dyeing, than cotton, or linen; their composition is less simple, and in consequence the attractions exerted by their elements upon the principles of other bodies are stronger and more numerous. See Part I. Div. VI.

(3) In cases, when colouring matters cannot be immediately united with the substance to be dyed, the combination is effected by the operation of a third body,

in consequence of intermediate affinity. Part I. Div. VI. Sect. 1.

The agents employed for fixing colours in cloths, stuffs, &c. are usually called mordants or bases.

3. *Of Mordants or Bases.*

(1) The most important mordants in common use are alumine, oxyde of tin, and oxyde of iron.

(2) Alumine has a very strong attraction for wool and silk, but a much weaker attraction for linen and cotton; it is employed in two states, either combined with sulphuric acid, or with acetous acid, which for this purpose, and for analogous purposes, is obtained in an easy manner from the decomposition of acetite of lead.

(3) The oxyde of tin at its maximum of oxydation, is applied to cloths, &c. in three forms of combination. 1. As nitromuriate of tin. 2. As acetite of tin; and 3. As tartrite of tin. These compounds are very powerful mordants, and act both on animal and vegetable substances.

(4) Two preparations of iron are employed as mordants, the red acetite and the red sulphate.

(5) Substances are occasionally used to facilitate the action of the common mordants, or to alter the shade of colour, such are tan, which itself is a species of mordant, tartar, acetite and sulphate of copper.

(6) Mordants in general do not act simply by rendering the dye permanent, but have always an influence on the colour produced. And in fact the colour may be considered as a simple property of the triple compound, containing the dye, the cloth and the mordant.

4. *Of the Simplest Dyes, or Simple Colours.*

(1) The colours denominated simple by dyers are four, blue, red, yellow, and black.

(2) Indigo is the only colouring matter used for dyeing *blue.* It is procured from different plants, such as the indigoferia tinctoria, and the isatis tinctoria. It combines with all the substances usually dyed, without the intervention of a mordant; and it is generally applied to them either dissolved in its common state in sulphuric acid; or combined in its deoxygenated state with lime water. In cases when cloths, &c. are dyed with deoxygenated indigo, they are at first green, but soon become blue by exposure to the atmosphere.

(3) The substances usually employed for dyeing *red,* are cochineal, archil, madder, brazil wood, and carthamus. And these colouring matters for the most part can only be permanently combined with cloths, &c. through the intervention of mordants. The colouring matters of cochineal, archil, madder, and brazil wood, are soluble in water; and in processes of dyeing they are usually precipitated from their solutions upon cloths, by means of nitromuriate of tin, or sulphate of alumine. The red colouring matter of carthamus is not combinable with water, but it is speedily dissolved in solution of carbonate of potash; and in this form it is generally applied to the substance to be dyed. The tint it communicates is considerably heightened by acids.

(3) The *yellow dyes* in common use are procured from weld, fustic, and quercitron bark, by the infusion of these substances in warm water, and they are generally combined with cloths, &c. by means of alumine. The red oxyde of iron has been lately proposed as a yellow dye by M. Chaptal.

(4) The tannogallate of iron is almost the only known black dye. It is combined with cloths, &c. at the moment of its formation, during the decomposition of the red sulphate of iron by decoction of gallnuts. Its colour is considerably heightened by the infusion of logwood.

5. *Of Compound Colours.*

(1) The dyes usually denominated compound colours, are formed by the mixture of simple colours. They are extremely numerous; and even when of the same class, differ in tinge according to the differences in their composition.

The most important of the compound colours, are mixtures of blue and red, of yellow and red, and of blue and yellow.

(2) Cloths, by being dyed successively with indigo, and cochineal or logwood, become violet, purple, or lilac, according to the intensity of the different dyes employed. When the blue dye prevails, violet is produced; and when the red, purple.

(3) Various tints of orange are produced by means of different successive combinations of cloths, with the colouring matters of weld or fustic, and those of madder or cochineal.

(4) Cloths are dyed of different shades of green, by means of indigo and quercitron bark. The colours are always applied to the cloth in succession; and oxyde of tin is generally used as a mordant.

6. *Of Calico Printing.*

(1) Calico printing is the art of dyeing cloths with different colouring matters, in such a manner as to pro-

duce upon them regular spots or figures. For this purpose the mordants necessary for the production of the different colours are applied to the surface of the cloths, &c. either by means of pencils, or of wooden engravings in relief; and, after dyeing, the colouring matter is easily washed out from that part of the cloth not acted upon by the mordants.

(2) The principal mordants employed in calico printing are acetite of alumine, and red acetite of iron. These substances are combined for application with a solution of gum or mucilage; and the cloth, after having received them, is washed with an infusion of cow-dung.

(3) The same colouring matter in calico printing is often made to produce several different colours, or shades of colour, according as the mordants applied differ in their nature or quantity. Thus, madder, with acetite of alumine, produces red, and with acetite of iron, brown; and quercitron bark, with the same mordants, in the same order, gives yellow, and olive.

7. *General Observations.*

(1) The permanency of colours depends in a great measure upon the strength of the affinity between the cloths, &c. and the colouring matters, whether they are in states of simple combination, or of combination by means of mordants.

(2) Colouring matters in general are compounded of many different principles, and they are for the most part decomposable by certain of the most powerful chemical reagents. In their combinations with cloths, however, they are seldom exposed to any other agencies than those of light, of air, and of alkaline sub-

stances; and those dyes are considered as durable which withstand the effects of washing, and of exposure to the atmosphere.

(3) The blues and blacks generally used are very durable dyes; but yellows, reds, and all the brighter colours procured from vegetables, for the most part fade more speedily; though it is said, that the oxyde of tungsten has been lately employed with great advantage for rendering them fixed and permanent.

DIVISION V.

OF METALLURGY.

1. *Of the Modes of procuring Metals from their Ores.*

(1) Metals are often found mineralised, either by sulphur, or oxygen, and in the last they are often combined with the phosphoric, arseniac, or carbonic acids.

(2) Sulphur is usually separated from metals by the application of heat, in a process called roasting; and they are deprived of oxygen by ignition with charcoal.

(3) In cases when metallic substances are enveloped in, or mingled with, earthy substances, from which they cannot be obtained in a free state by mechanical agents; they are separated during fusion by means of certain compound salts, in consequence of their great specific gravity.

(4) Acids, and other chemical reagents, are often used in operations upon the more precious metals, which in these cases are first exhibited in the states of oxydes, and are afterwards rendered metallic by the agency of heat and of inflammable substances.

2. *Of the Formation of Alloys, and other Metallic Compounds.*

(1) Alloys are formed by bringing different metals together in a state of fusion, and they are much used for common purposes of life.

(2) In general the alloys of gold, silver, and copper, are employed as the medium of exchange; and the standard gold of Britain is composed of 11 parts gold and 1 of copper; and the standard silver of 15 parts silver and 1 of copper.

(3) The alloys of tin, and of copper are used for forming drinking vessels, lamps, mathematical instruments, bells, and different utensils employed for purposes in which fusibility, ductility, weight, durability, and impermeability to water are required.

(4) But one of the most important of the metallic compounds is steel, which is employed for making all such instruments as demand great hardness, strength, and elasticity. The best steel contains about $\frac{1}{200}$ carbon. Its properties are wonderfully influenced by different applications of heat.

(5) The alloys, as well as the pure metals, are made of regular forms, by being cast in moulds made of substances infusible, and unalterable by heat; and they are polished and ornamented by different mechanical compressions or abrasions of their useless parts.

3. *Of Soldering.*

(1) Soldering is the art of fastening together different metals, by the application of some metallic compound in fusion, to the parts to be united.

(2) Different alloys are generally employed as solders;

and they should be always more fusible than the metals to which they are applied, and possessed of a strong affinity for them.

(3) Solders for lead, are composed of two parts of lead to one of tin. Pieces of copper are united by means of an alloy of copper and tin. Two parts of silver and one of brass compose silver solder.

(4) Soldering is performed by means of the blowpipe, heated irons, &c.; and to prevent the metals from being oxydated, or to free them from impurities, resin, borax, and other substances are employed.

4. *Of Plating, Gilding, &c.*

(1) The surface of one metal may be covered by a thin stratum of another metal, in many different ways.

(2) Iron is plated with silver by means of hard solder; and silver is often made to cover the surface of copper and some other metals, by means of simple cementation; or by being rubbed or burnished upon them, when in a state of minute division.

(3) Gold is made to adhere to other metals generally either by being amalgamated with mercury, or by being applied in a state of minute division. In the case of amalgamation the mercury is driven off by heat from the metallic surface, and the gold only remains. Finely divided gold becomes easily attached to a metallic surface by pressure, or by friction.

(4) Iron and copper are readily covered with a coating of tin, by being immersed into that metal when in a state of fusion.

5. *Of the Analysis of Metallic Compounds.*

(1) Metallic compounds are so numerous, that it is

impossible to describe with accuracy, any general mode of discovering their constituent parts.

For the purpose of analysis, a number of reagents must be employed; and the greater part of the instruments of modern chemistry brought into action.

(2) Different acids, and particularly the nitrous, are made use of for oxydating or dissolving metallic compounds. The prussiate of potash is a good test for the presence of red oxyde of iron, and other metallic oxydes in solutions.

(3) Silver and lead are precipitated by means of muriatic acid; gold and platina are known by the facility with which they are revived. The quantity of tin, zinc, or iron, in any alloys, may be discovered from the quantity of hydrogen produced during their action upon sulphuric acid.

(4) But the habits of performing the processes relating to this part of metallurgy can only be attained by long experience, and by studying the works of the best writers on the subject. Kirwan, Klaproth, Vauquelin, Hatchett, &c.

DIVISION VI.

OF THE MANUFACTORY OF GLASS AND PORCELAIN, ETC.

1. *Of Glass Making.*

(1) Glass is formed by the fusion of potash, or soda, with sand chiefly containing silicious earth. It is made of different degrees of density by means of oxyde of lead; and it is rendered transparent and colourless by certain substances containing oxygen.

(2) The best kind of flint glass is composed of about

120 parts of white silicious sand, 40 parts of pearl ash, 35 of red lead, 13 of nitre, and ·25 of black oxyde of manganese.

(3) Glass is coloured blue by the oxyde of cobalt; red by the oxyde of gold; green by the oxyde of copper, and yellow by the oxydes of antimony and lead.

2. *Of the Manufactory of Porcelain, Earthenware, &c.*

(1) The component parts in general of porcelain and earthenware are silex, alumine, lime, and, in certain cases, metallic oxydes. The quantity of silex is commonly about two-thirds; that of alumine, from a fifth to one-third, and that of lime, from one-fifth to one-twentieth.

(2) Alumine and silex form, with water, a paste of softness and ductility capable of being easily kneaded; and by means of lime, they are rendered more susceptible of combining by incipient fusion, so as to form hard and permanent masses.

(3) Porcelain and earthenware are glazed by means of different mixtures of earths with alkaline substances, oxyde of lead, &c. and they are coloured nearly in the same manner, and by the same substances as glass.

DIVISION VII.

OF THE PREPARATION OF FOOD, DRINK, ETC.

1. *Of the Preparation of Food.*

(1) The food taken into the stomach should be capable

of being easily digested and converted into chyle. The gelatine, fat, and fibrine, in animal compounds, are the most nutritive substances we are acquainted with; and after them follow the sugar and mucilage in vegetable productions.

(2) In the preparation of food by heat, great care should be taken to prevent any part of it from being decomposed. Stewing, by means of water, appears to be one of the most economical modes of preparing both animal and vegetable food; but in baking and roasting a portion of nutritive matter is always destroyed. As gelatine, mucilage, and sugar, are all soluble in hot water, they may be formed into soups, which are at once nutritive, and pleasant to the taste.

2. *Of the making of Wine, Beer, Alcohol, &c.*

(1) Wines are procured by the fermentation of the juice of grapes; and in this process the saccharine matter of the fruit is slowly converted into alcohol, at the same time that much carbonic acid is evolved.

(2) Ardent spirits are obtained by distillation, from substances containing saccharine matter, which has fermented so as to form alcohol; and they differ in quality chiefly in consequence of the different nature of the aroma and extractive matter combined with them.

(3) Beer, porter, and ale are made from the fermented juice of barley and the infusion of hops; and they appear to consist chiefly of different proportions of water, mucilage, alcohol, sugar, and bitter principle.

DIVISION VIII.

OF THE MANAGEMENT OF HEAT AND LIGHT, ARTIFICIALLY PRODUCED.

1. *Of Combustion.*

(1) In all processes of combustion, the fuel must be situated in such a manner, as to be constantly exposed to fresh atmospheric air.

(2) The phænomena generally connected with combustion, are radiant heat, common communicated heat, and light; and these effects occur in very different degrees in different instances.

(3) Coal, coke, charcoal, and wood, are the substances generally employed in purposes where heat only is required. But tallow, spermaceti oil, wax, and other substances which burn with flames, are used for producing light.

2. *Of open Fire-places.*

(1) The grates of such fire-places as are chiefly designed for heating the air of apartments should project as much as possible, and their backs and sides ought to be formed by substances which are bad conductors of heat. Chimneys likewise should be composed of similar substances, and their lower orifices ought to be no larger than may be absolutely necessary for a free circulation of air.

(2) For increasing the radiation of heat during the

combustion of fuel, coals may be mingled with certain incombustible substances, so as to form fireballs.

(3) The great principle in the management of common fires is to suffer as little as possible of the volatile parts of the fuel to pass off unconsumed by the chimney; and to communicate as much heat as possible in an equable manner to the air in every part of the room to be heated.

3. *Of Furnaces, and different closed Fire-places for Culinary Purposes.*

(1) Furnaces, and other similar fire-places, should be constructed in such a manner as to enable as great a quantity as possible of the heat produced by the combustion of fuel to be applied immediately to the vessels to be heated. For this purpose they should be composed of nonconducting substances, and their form ought to be such as to cause the heated air, or flame, produced in them, to strike immediately against the bottoms of the vessels to be heated.

(2) For culinary purposes these vessels ought to be composed of metallic substances, which are good conductors of heat; and their lower surfaces should be as large as possible, and of such a form as to enable the flame and heated air which strikes against them, to break, and to play over them with force in different currents and directions.

(3) Steam may be employed with great advantage for heating fluids, and for keeping them warm. It can easily be carried from place to place by means of tubes, and the apparatus required for applying it is light and simple.

4. *Of Candles, Lamps, &c.*

(1) The wicks of candles and lamps seem to act, simply by conveying the inflammable matter in a fluid form regularly and slowly to the place of combustion, in consequence of capillary attraction.

(2) In all lamps and candles the place of most intense combustion is a little above the point at which the oil is volatilized, and where the supply of air is greatest; and in all cases, the wick ought to extend but very little beyond that point.

(3) During the combustion of candles, in consequence of the want of a supply of air to the middle of the flame, a small portion of inflammable matter is generally decomposed without being consumed, whence the production of smoke; but in the Argand lamp, in which the wick is exposed both externally and internally to air, this phænomenon does not take place.

(4) The photometer described in Part II. Div. II. is of great use in all experiments upon artificial light; and by means of it, the intensity of the light produced during the combustion of different bodies may be ascertained, so as to be compared with their relative consumptions, in the process.

OUTLINES OF A COURSE OF LECTURES

ON

CHEMICAL PHILOSOPHY.

Ante omnia ergo, duo magna in Mundo, Laboratoria esse scias, unum Naturæ, alterum Artis.—Beccher. *Physic. Subter*. page 1.

But above all things it is to be understood, that there are in the world two great Laboratories, one of Nature, and the other of Art.

ADVERTISEMENT.

The Lectures on Chemical Philosophy, for 1804, will be divided into two distinct parts: Chemistry in its Connection with Natural Operations; Chemistry in its Connection with Artificial Operations. The first part will be delivered in the morning, the second in the evening.

The following pages contain the outlines of both series. The views taken in them are necessarily very limited. My design has been to give a general idea of the plan and order of the course, and not a minute detail of all the different objects to which it will relate.

Albemarle Street,
Jan. 12*th*, 1804.

OUTLINES OF A COURSE OF LECTURES

ON

CHEMICAL PHILOSOPHY.

PART I.

CHEMISTRY, IN ITS CONNECTION WITH NATURAL OPERATIONS.

1. *Introduction.*

Chemistry, in its connection with the operations of nature, is highly worthy of an accurate examination. It unfolds the causes of many important phænomena; it enables us to reason concerning those properties of bodies which most immediately concern us, and to predict their alterations; and it developes to us sublime views of the order and harmony belonging to the different parts of our system. This branch of science has been slowly formed, in consequence of minute observations made upon natural events, and of experiments in which natural agents have been placed in new relations: and though much remains to be discovered in it, yet the facts already ascertained are sufficient to prove, that all the different known substances belonging to our globe are subjected to the chemical laws; and that the most extensive and important chemical changes are continually taking place in the solid matter of the globe, the ocean, and the atmosphere.

2. *Of the Nature of the Solid Parts of the Globe.*

The solid matter of the globe, as far as it has been investigated, consists chiefly of rocks or earthy substances, forming hills and mountains, or arranged in strata. Rocks, or strata, are divided into five classes; primitive, transitional, secondary, alluvial, and volcanic.

Primitive rocks, or strata, are those which exhibit no vestiges of organic remains; they are found at the greatest depths below the surface, and they constitute the bases of the highest mountains. They are composed of masses, which are either aggregates, or simple stones: granite, and the granitic rocks, the porphyries and sienites, are of the first kind; and silicious schist, argillaceous schist, serpentine, hornstone, granular limestone, and shoerl, are of the second kind.

The transitional rocks generally unite the primitive and secondary rocks, and they afford a few vestiges of the remains of marine animals. The aggregates composing them are toadstone, and different traps; and the simple rocks are chiefly schist, and limestone.

The secondary rocks are such as abound in many parts with the vestiges of shells, and marine productions; they are usually stratified. The aggregates belonging to them are grunstein, schistose porphyry, toadstones, and sandstones; and the simple rocks are limestone, chalk, gypsum, ironstone, wacké, and secondary schist; and these substances often alternate with masses of coal.

The alluvial strata are such as have been deposited in late times from the agency of water; they often contain the bones of land animals; and they are seldom in a state of firm aggregation, being composed, for the most part, of calcareous and silicious sands, clays, and tufas.

The volcanic productions are the different lavas, and stones altered by fire.

The parts of the primitive, transitional, and secondary rocks, are often found in regular forms, as crystals. These rocks, in many instances, abound with metalliferous veins, which intersect them in different directions.

The most abundant of the simple principles contained in rocks and strata, are the primitive earths. The metals in them are found either native, or in combination chiefly with sulphur, or oxygen.

Soils usually partake of the nature of the aggregates or simple stones on which they rest; but their parts are in a state of minute division, and are generally mixed with animal or vegetable decomposing matters.

3. *Of the Nature of the Sea, and of Water.*

The immense mass of waters composing the ocean, differs but little in various parts, as to the saline compounds it holds in solution; but generally the largest quantities are found near the tropics, and the smallest quantities near the equator. The waters of lakes, rivers, and springs, usually contain comparatively small portions of saline matters, which are very different in their nature in different cases. The purest water is that precipitated from the atmosphere in rain or dew, but even in this state it is saturated with air. Water when it becomes solid or ice, gives out the air with which it was combined, and its specific gravity is diminished.

The elementary principles of which water is believed to be composed are oxygen and hydrogen. The bases of the salts that it usually holds in solution are the alkalies, or the alkaline earths, which are combined with the sulphuric, muriatic, or carbonic acid.

4. *Of the Nature of the Atmosphere.*

The atmosphere is the great body of elastic fluid, which everywhere surrounds our globe. Its density diminishes in proportion as its height increases. It is the receptacle of a great number of aëriform fluids, that are produced, or developed, on the surface of the earth; but the principal constituent parts of it are nitrogen, and oxygen, in proportion as four to one, and which are mixed with carbonic acid, and hold in solution water. The chemical composition of the atmosphere, as to its permanent elements, is nearly the same in all its different parts; the vapours that float in it, its temperature, and its relations to moisture, in different places, are probably the great causes that modify its effects upon living beings.

5. *Of the Elementary Principles, and the active Powers of Matter.*

Many principles are common to the three great divisions of the globe; and the ponderable matter of all the different known compounds, as far as it has been investigated, appears to be formed by the combination of a few elements. These elements are, six simple earths, six alkaline substances, twenty-two metals, three acids, three inflammable solids, and three simple gases. In their natural arrangements they are acted on by attraction: and to the agencies of this power, as chemical affinity; and to the effects of heat, light, and elctricity, produced by imponderable substances, as yet but little understood, almost all the corpuscular changes of dead matter, either immediately or remotely belong.

6. *Chemical Changes in the Solid Parts of the Globe.*

The changes taking place in the solid parts of the earth, except in a few cases, are slow and progressive; and they generally arise either from the action of inflammable bodies, from that of air, or of water. The phænomena of volcanos have their origin, probably, in the mutual agencies of inflammable bodies and metals, in the bosom of the earth; but their intense heat depends upon the exposure of the acting matters to the atmosphere, upon actual combustion. Great alterations are produced in the most solid rocks, by the agency of water: this fluid is absorbed by earthy bodies; and when converted into ice on their surfaces, it tends, by its expansive properties, to separate their parts from each other: some of the earths are soluble in it, particularly lime, and its compounds; and when these substances form parts of rocks, they are gradually altered, and deposited in new forms. The oxygen of the atmosphere is constantly attracted by the greater number of the metallic combinations; and, in consequence of its agencies, rocks which contain them, often undergo changes in their states of aggregation, become softened, and are rendered subservient to vegetation.

7. *Chemical Changes in the Sea, and in Water.*

The water of the sea is constantly agitated by the tides and winds, and, in consequence, all its different parts are mixed together, and preserved in a state of saturation with air.

The dead animal and vegetable substances which it contains, whether originally belonging to it, or carried into it by rivers from the land, are prevented from undergoing the rapid putrefactive process, by the agency of the saline matter with which it is combined; and they probably are rendered subservient to the nourishment of marine plants and animals. Water is decomposed in a number of natural processes, by the agency of vegetables, by combustible bodies, and by electricity; and, in many cases, one of its elements becomes fixed, whilst the other is disengaged in a free state.

8. *Chemical Changes taking place in the Air.*

Air is possessed of a strong attraction for water, and the quantity it is capable of dissolving is greater in proportion as its temperature is high. When strata of air, unequally heated, and saturated with water, come in contact with each other, moisture is deposited, which, according to circumstances, appears either as clouds, mists, rains, dew, hail, or snow: and this deposition is the source of our springs and rivers. The oxygen of the air is essential to combustion, is absorbed in that process, and the heat and light produced depend on the circumstances of its agency. Air enters slowly into combination with a number of substances, and either tends to decompose them, or causes them to enter into new combinations. Air is absolutely necessary to the life of animals: in its free state it enters into the lungs; and its oxygen, and probably portions of its nitrogen, are combined with the principles of the blood. In its form of solution in water it is absorbed by fishes; and it abounds in the depths of the ocean, where the pressure tends to combine it in large quantities. Air is constantly active in supporting vegetation, and in modifying the substances contained in soils; and its diversified agencies promote the fertility of the earth.

The meteors appearing in the atmosphere, which cannot be referred to electricity, have only very lately become subjects of investigation, and as yet are but little understood. They seem to be heavy bodies, inflamed in the higher regions of the air: various theories have been formed concerning their origin.

9. *Of the Chemical Agencies of Heat in producing Natural Changes.*

The heat belonging to our globe is principally derived from the sun, but it is sometimes evolved in consequence of the chemical agencies of common matter. It varies in degree in different parts of the surface of the earth, generally according as their exposure to the sun is different, and according as they are endowed with different powers of reflecting, absorbing, and conducting it. Heat is possessed of the agency of expansion; and, in numerous cases, in consequence of its operation, solids are converted into fluids, and fluids into aëriform substances. By the changes in the specific gravity of air, in consequence of changes in its temperature, the winds in the atmosphere are principally occasioned; and the currents in the ocean are influenced, and, in some cases, produced by alterations in the degree of its heat. This agent is very efficient in occasioning decompositions, and new combinations; and by means of it the most important changes are constantly effected in the arrangements of the principles of bodies; and elements, apparently inert, are called into a state of activity.

10. *Of Light, and its Chemical Agencies in Nature.*

The rays of the sun, when analysed by the prism, appear to be of different kinds; and besides those that produce light, and those that produce heat, there are others invisible, which occasion peculiar chemical changes. These facts render it very difficult to ascertain with perfect accuracy, the peculiar and distinct agencies of the different parts of the solar beam, or of light, as it usually appears. In considering generally the effects of the luminous and the chemically acting rays; it would appear that they tend to decompose bodies in a way perfectly different from heat. In a number of instances, oxygen gas is disengaged in consequence of their operation; and the uniformity of the constitution of our atmosphere is probably owing to this circumstance. Crystallization is affected by them; the colours of bodies are modified by them: and their chemical influence upon organized matter is distinct, and of great importance.

11. *Of the Effects of Electricity in Nature.*

The medium which in its active state produces electrical effects, appears to be almost universally diffused, and it is capable of being put into motion both by chemical and mechanical means. When bodies change their forms of aggregation, electricity is usually developed, and either a positive or a negative state induced. During evaporation, and at the time of the precipitation of moisture from the air, atmospheric electricity is uniformly exhibited; and, in its accumulated states, in passing to, or from the earth, it produces the phænomena of lightning. The appearance of the aurora borealis is probably owing to electrical changes taking place in the air round the poles. By the extensive action of electricity various changes in the forms of bodies are constantly produced. In its state of galvanism, its activity is peculiarly exerted on water, and on solid bodies; and it probably influences the phænomena of earthquakes, and other rapid changes which occur in the bosom of the earth.

12. *Of the Relation of Chemical Changes to Vegetable Life.*

The alterations taking place in common matter are in no cases capable of forming organic bodies, or structures possessed of the faculty of reproduction; but they are connected with the support and nourishment of such bodies; they are essential to their existence. Plants derive their food either from the soil in which they grow, or the atmosphere by which they are surrounded; and the phænomena of their vegetation and their growth, depend upon the assimilation of new matter to their organs, in consequence of the exertion of the living power, and of chemical affinity. The principles of air and water are absorbed by plants, and the organizable matter contained in soils, carried, in solution, into the vessels of the alburnum by their roots. By the agency of the solar light, inflammable matter is produced in their leaves, and oxygen evolved from them. Carbonic acid is apparently decomposed by vegetables: and this principle, and other principles noxious to animals, precipitated from the atmosphere, in combination with water, become their essential food. Thus dependent, during life, upon chemical changes, vegetables after death, are wholly submitted to them; and their decomposition, by external agents, soon restores to inorganic nature those elements of which it had been, for a short time, deprived; gives to them a new arrangement; and disposes them to assume new forms of existence.

13. *Chemical Changes subservient to the Functions of Animals.*

The principles of animal matter are much more numerous, and more complicated in their arrangements, than those of vegetable matter. In irritable and sensitive action, the laws of chemistry are submitted to the powers of life, and their distinct and peculiar operation is seldom or never perceived. Solid and fluid nutritive substances, whatever their nature may be, undergo peculiar changes in the digestive system, and are converted, in consequence of unknown operations, into fluids in all cases analogous. By these means, and by the absorption of air in respiration, the waste of matter taking place in the organic frame is supplied; and the different elements are made subservient to the purposes of animated nature. Heat in the animal body is constantly regulated by the living functions; and thus an agent, most powerful in modifying common matter, as well as electricity, appears in this case, as the passive instrument of a superior and more active principle.

14. *The general Economy of Nature, and of the Connection of the different Causes on which it depends.*

By the laws of gravitation the globe is made to revolve round the sun, in such a manner as to expose all the different parts of its surface at different times to light. From the nature of these laws, inequalities of temperature are produced, and changes in the state of the air and ocean, absolutely essential to the existence of living beings. The form of the earth, and the irregularities belonging to it, are of infinite importance in the economy of nature. By means of mountains, the course of the winds is regulated. They are the sources in which the waters of the atmosphere are collected; and they supply the decay of soil taking place in valleys and plains. Rocks and the earthy strata, which contain metals, and other substances equally useful to man, are fitted, by their position, to form a boundary beyond which the influence of water and the atmosphere cannot penetrate; and by means of them such matter as is capable of being organized is confined to the surface of the earth. The water derived from the sea by evaporation is again returned into its bosom by means of rivers. Amidst the various chemical changes taking place in the air, it is constantly preserved in a state most proper for respiration. Animals and vegetables are made to support each other. And by means of a few simple laws, displaying one great and perfect design, all the changes of matter are rendered subservient to the well being and happiness of man, and of the whole living creation.

15. *Of the various Alterations which the Globe has undergone; Geological Systems, and concluding Observations.*

In the investigation of the history of nature, the understanding is necessarily led to reason from the present order of things, concerning their former arrangements, and to conjecture with regard to their future changes. It requires no minute knowledge to determine, that very considerable alterations have taken place in the surface of the earth within periods ascertained by history. The forms of mountains have been changed by volcanos, and by the agency of water; the beds of rivers have been altered; the solid matter carried into the sea has modified the appearances of the shore. In speculating on these facts, in their relation to the origin of the general appearances of our globe, geologists have been led to conclude from the existence of crystallized masses in both the primitive and secondary countries, that a considerable part of the solid matter, composing them, once existed in a state of fluidity; and very different theories have been formed concerning the agent which occasioned its solution; in one hypothesis, water being made the primary cause; and in another, fire acting under the pressure of the ocean. In the present state of our knowledge, it is perhaps impossible to form accurate conclusions on this subject, or on the ultimate changes which our system is destined to undergo; the analogies deduced from our artificial operations are extremely imperfect; and as we are acquainted with only a very minute part of the materials of the globe, there is great reason to suppose, that powers have been, and may be called into action in modifying it, of which we can form no ideas; and which it has pleased the Divine Will to conceal from us in wisdom.

PART II.

CHEMISTRY IN ITS CONNECTION WITH ARTIFICIAL OPERATIONS.

I. OF THE GENERAL PROPERTIES OF MATTER, AND THE AGENCIES OF IMPONDERABLE SUBSTANCES.

1. *Introduction.*

A considerable number of natural substances have been submitted to chemical processes: and by means of various instruments and inventions, they have been exhibited under new circumstances, their forms have been changed, and their hidden qualities discovered. Chemistry, as a science of operation, is of great importance: in its theoretical relations it has contributed to extend the powers of the mind, by presenting to it a number of new and interesting objects for contemplation; and in its practical results, it has tended to diminish our wants, and to refine and increase the sources of our pleasures.

Attraction and its Agencies.

Different species of matter tend to unite with different degrees of force. This is the general fact of chemical attraction: which according as it is exerted under different circumstances, is governed by different laws. Its influence is general, and modified only by the effects of heat, and the other imponderable agents.

2. 3. *Of Heat or Caloric, its Excitement and Agencies.*

Heat or caloric is the great expanding power: it is capable of being communicated by bodies to each other; and the laws of its communication constitute the laws of temperature. It exists likewise in a free state, or as radiant heat; and, in this case, it is capable of being reflected and refracted. The extensive operation of heat on bodies is often connected with changes in the forms of their aggregation. It is possessed of great powers in producing chemical alterations in substances; for as it expands them differently, so it diminishes in different ratios the affinities of their particles for each other. The instruments used in experiments upon heat, are thermometers, pyrometers, and calorimeters, &c.

4. *Of Light, and its Operations in Chemistry.*

Light is a chemical agent of considerable importance in artificial processes. In consequence of its properties of being reflected and refracted, it is capable of being accumulated, or dispersed. It is applied in experiments, either in its compound state, in which it is mixed with heat; or in its decompounded state, in which its different rays occasion different changes.

5. 6. 7. *Of Electricity, and Galvanism.*

Electricity in its various states of accumulation, produces different effects. In general, its presence is denoted in substances by their powers of attracting, or repelling light bodies. It often appears in the form of fire; and it is possessed of very powerful chemical agencies.

It is excited by various causes, and exhibited by means of a number of different instruments. In the galvanic apparatus, it produces an extensive series of important and beautiful effects, which have been lately discovered, and are still subjects of investigation.

General Observations on the Active Properties of Matter, and on the Art of Experimenting.

Though the immediate causes of the active properties of matter are but little understood, yet the laws by which they are supposed to act are simple expressions of facts. The knowledge of these laws, and the investigations concerning them, have led to many important discoveries in the arts of life: and, guided by them, the chemist is capable of imitating the operations of nature, and of producing new operations: he is enabled to analyse, and to compound; to discover simple principles, and to ascertain their arrangements.

II. OF UNDECOMPOUDED SUBSTANCES, OR SIMPLE PRINCIPLES; THE METHODS OF PRODUCING THEM, AND THEIR APPLICATIONS.

8. *Preliminary Remarks.*

Simple principles are those substances which have not as yet been composed or decomposed by artificial means. Many of them are found in nature, and many are producible from their compounds by art. The simple principles at present generally acknowledged by chemical philosophers, are 43; which when considered as to the similarity of their most striking properties, may be divided into six classes.

Of the Simple Gases possessed of no Acid Properties; the First Class.

The simple gases possessed of no acid properties, are three in number; oxygen, hydrogen, and nitrogen; they are nonconductors of electricity, and but slightly soluble in water; they are capable of being produced by various operations. Oxygen is essential to combustion; hydrogen is inflammable; and nitrogen is one of the elements of nitric acid.

9. *Of the Simple Inflammable Solids; the Second Class.*

The simple inflammable solids are, phosphorus, sulphur, and carbon. Phosphorus is an artificial product; carbon, and sulphur are found in nature. They all burn when heated, at different temperatures, in contact with oxygen.

10. *Of the Metals; the Third Class.*

This class contains twenty-two undecompounded substances; they are, platina, gold, silver, mercury, copper, tin, lead, iron, zinc, antimony, bismuth, arsenic, cobalt, nickel, manganese, tungsten, uranium, molybdena, titanium, tellurium, chrome, columbium. Metals are separated from their compounds by various metallurgical processes: when combined with sulphur, they are freed from it by the agency of heat and of re-agents; and in cases when oxygen is the mineralising substance, it is detached from the ore by means of ignited charcoal or other inflammable bodies.

The metals are possessed of very high specific gravities, of opacity, and brilliancy of appearance: they are all combustible at certain temperatures, when in contact with oxygen; some of them, as zinc and tin, requiring only a low red heat, and others, as gold and silver, an intense white heat.

11. *The Simple Earths; the Fourth Class.*

These substances are distinguished by their insolubility in water, their incombustibility, and their want of electrical conducting power; they are, silex, alumine, zircone, glucine, ittria, and, as it is supposed, agustine: the processes by which they are obtained pure, are, for the most part complicated, and connected with the application of a number of different re-agents.

The fixed Alkaline Substances; the Fifth Class.

These bodies are six; amongst them, potash and soda are very soluble in water, and are usually denominated the fixed alkalies. Strontian, barytes, lime, and magnesia, are generally called alkaline earths; they are less soluble in water than the fixed alkalies. All the simple alkaline substances are incombustible, and capable of being combined with acids, and with sulphur.

The Undecompounded Acids; the Sixth Class.

These substances are, the muriatic acid, the boracic acid, and the fluoric acid. They are combinable with water and the alkalies; they redden vegetable blues. The muriatic acid, and the fluoric acid, are permanent gases. The boracic acid, is a crystallized solid.

Applications and Uses of the Simple Substances.

Amongst the simple substances, the metals are the most important in their applications to the common purposes of life; their uses are various and extensive. The earths, alumine, and silex, form the bases of various manufactures. Lime is principally used as a cement. Oxygen, the alkalies, and the muriatic and boracic acids, are amongst the most powerful of chemical reagents.

III. OF BINARY COMPOUNDS, THEIR PROPERTIES AND APPLICATIONS.

The binary compounds owe their origin to the union of two simple principles; and they are usually composed and decomposed by the simplest laws of attraction. They differ considerably in their properties; but a simple classification of them into five kinds, is obtained, by considering the substances of which they are composed.

12. 13. 14. *Binary Combinations of Oxygen.*

The bodies of the first class contain oxygen, as one of their elements; a principle, which has the greatest tendency to combination, and which is the most active amongst material agents.

The binary compounds of oxygen, are either decomposable acids, possessed of the sour taste, and the power of reddening vegetable blues; or oxydes, which are insoluble, or sparingly soluble in water, and which are incapable of altering vegetable colours.

Oxygen, by combining with different bodies in different proportions, forms compounds possessed of very different properties.

Of the binary compounds of oxygen, water contains 15 parts of hydrogen, and 85 of oxygen.

Nitric acid, nitrous gas, and nitrous oxyde, have nitrogen for their basis; and contain respectively 71, 56, and 37, of oxygen, in 100 parts. They are amongst the most decomposable of the binary compounds.

The phosphoric and the phosphorous acids consist of oxygen and phosphorus; which, in the first, are united in the proportion of 1·6 to 1.

The sulphuric acid contains about 1·7 parts sulphur, and 1 of oxygen. The sulphureous acid contains a smaller proportion of oxygen: it is a permanently elastic fluid.

Three binary compounds are known, containing oxygen and carbon; charcoal, gaseous oxyde of carbon, and carbonic acid; the two first are inflammable.

13. The metallic acids, which are the arsenious, and the arsenic acid, the molybdic, and the chromic acid, are formed by the union of oxygen, with arsenic, molybdena, and chrome. These metals, as well as all the other metals, by combining with a small proportion of oxygen, form oxydes; and some metals, for instance, iron and lead, by different combinations, form different oxydes.

14. The oxygenized and hyperoxygenized muriatic acid, are produced by the combination of different proportions of oxygen with muriatic acid; they are decompounded by combustible bodies with the production of heat and light.

15. *Binary Compounds, containing Hydrogen; the Second Class.*

Hydrogen is capable of combining with, at least, three simple substances besides oxygen. By uniting to nitrogen in the proportion of 20 parts to 80, it forms ammonia, or volatile alkali. With sulphur, it produces sulphuretted hydrogen gas, which is possessed of acid properties. In phosphoretted hydrogen, it is attached to phosphorus; and this compound inflames when suffered to pass into the atmosphere. From some late experiments it appears very probable that there are no binary compounds of carbon and hydrogen.

16. *Binary Compounds, containing Sulphur; the Third Class.*

Sulphur is possessed of various affinities; its binary compounds are denominated sulphurets.

The metallic sulphurets are formed by the union of sulphur with the metals.

The alkaline sulphurets contain the alkaline substances as their bases.

The compounds of sulphur and phosphorus are very inflammable. The compound of sulphur and muriatic acid is possessed of some singular properties.

The Binary Compounds of the Metals with Phosphorus, Carbon, and with each other; the Fourth Class.

Phosphorus is capable of combining with the greater number of metallic substances: the phosphorets are possessed of the metallic splendour, and are very combustible.

The most important of the metallic compounds containing carbon, is steel, or carburet of iron, which contains from $\frac{1}{100}$ to $\frac{1}{200}$ of carbon. In plumbago, or the hypercarburet of iron, the quantity of the carbon exceeds very much that of the metal.

The binary alloys are formed by bringing two metals, possessed of affinity for each other, together; one of them at least being in a state of fusion or solution. Amongst them the best known are, brass, bronze, the alloys of gold, the fusible compounds of lead, and the amalgams.

The Binary Compounds of the Earths and Alkalies with each other, and the Acids; the Fifth Class.

The binary compounds containing earths only, have as yet been very little examined. Alumine and silex, may be made to form a permanent union. The fixed alkaline substances are capable of combining with most of the earths. The basis of glass is equal parts of potash, or of soda, and silex.

The alkaline substances, by uniting with the undecompounded acids, produce certain compound salts.

Of the Application and Uses of the Binary Compounds.

The applications of the binary compounds are very numerous. The nitric and sulphuric acids, are employed in many of the arts, and particularly in the processes of metallurgy and dyeing. The metallic oxdyes are the most important of our pigments. The oxygenated muriatic acid is used in bleaching. Steel, and metallic alloys, form some of the most important of the instruments employed for the common purposes of life, and in the processes of experiment.

The general series of changes produced by the formation and decomposition of the binary compounds, particularly in the instances in which oxygen is concerned, constitute some of the most instructive of the operations of modern chemistry; and they are connected with many beautiful appearances.

IV. Of Ternary, Quaternary Compounds, etc. their Agencies and Uses.

Classification.

A few only of the ternary or quaternary substances are capable of being composed by art immediately from their elements. Many of them are products of organized bodies, and their nature is discovered chiefly by analysis; considering their composition, they will admit of a division into five classes.

17. *Compounds, containing chiefly Oxygen, Hydrogen, or Carbon; the First Class.*

These compounds are usually found in the vegetable kingdom; and their composition, and their properties, are very diversified; many of them have been called vegetable oxydes. The hydrocarbonates, alcohol, ether, volatile, and fixed oils, wax, and resin, consist of different proportions of hydrogen and carbon, united to small portions of oxygen. Sugar, gum, tannin, colouring matter, and the extracts soluble and insoluble in water, contain considerable quantities of oxygen, combined in different proportions with carbon and hydrogen, and sometimes with nitrogen.

Of the Acids, containing Oxygen, Hydrogen, and Carbon; or the Vegetable Acids; the Second Class.

The vegetable acids are eleven in number.

The acetic acid, the tartaric, the oxalic, the citric, the malic, the succinic, the benzoic, the camphoric, the suberic, the mucous, and the gallic acids. The oxalic acid is probably that which contains the largest proportion of oxygen; and the gallic acid that which contains the least. They are all soluble in water; and decomposable by heat.

18. *Of the Compounds, containing Oxygen, Hydrogen, Carbon, and Nitrogen, possessed of no Acid Properties; the Third Class.*

These compounds are found for the most part in the animal kingdom: the relative proportions of their principles are unknown; one of their most characteristic properties, is the facility with which their composition is altered. The most important of them are, gelatine, albumen, animal mucilage, fibrine, and animal oil; the three first only are soluble in water, and precipitable by tannin.

Of the Acids, containing chiefly Hydrogen, Carbon, Nitrogen, and Oxygen; the Fourth Class.

Amongst these substances, some are found native in animal solids and fluids, others are produced during their chemical alteration. The native animal acids are, the formic, the bombic, the laccic, the sebacic, and the uric acids. The factitious acids are, the lactic and the prussic acid. All the animal acids are decomposable by heat; and the prussic acid contains only a very minute portion of oxygen.

Ternary, and Quaternary Compounds, containing Metals, Earths, and Alkalies.

The metals are capable of combining with each other in ternary and quaternary union; but the properties of very few only of the more compound alloys have as yet been studied.

Ternary and quaternary combinations of the earths, constitute the basis of porcelain.

The fixed alkaline substances are capable of entering into union with different earths, so as to form with them single compounds.

Uses and Applications of the Ternary and Quaternary Compounds.

The vegetable and animal compounds are applied to very important uses in common life. Many substances in the first and second classes are employed as articles of food. The inflammable compounds afford us the means of procuring, artificially, heat and light. On the union of colouring matters with the substances used for clothing, either immediately, or by means of mordants, the art of dyeing is founded. The compounds in the three last classes, though of more limited application, are yet essential in some of the processes of various arts.

V. Of Substances composed of different Compound Bodies, or of Compound Bodies and Simple Bodies.

General Observations.

The existence of the more compounded bodies is owing to very complicated affinities. In general they are difficultly produced, but easily decomposed; and this is peculiarly the case, when the substances constituting them contain as elements, the simple gases. The more compounded bodies may be divided, according to their physical relations, into five classes.

19. *Saline Compounds; the First Class.*

The saline compounds are substances, containing, as one of their constituent parts, an acid, an alkali, or an oxyde. In general, they are soluble in water, incombustible, and nonconductors of electricity.

The saline compounds, containing the acids united to the alkaline substances, metallic oxydes, or earths, are very numerous; every acid being capable of forming a great variety of combinations; their names are derived from the acid and the basis.

The alkaline substances are capable of combining with many other bodies besides the acids; they enter into union with oil, albumen, alcohol, &c. Their combinations with oily substances are soaps.

Certain of the metallic oxydes in combination with ammonia, and some other substances, form powerful fulminating compounds.

20. *Compounds of the Metals and Earths, and Mineral Substances; the Second Class.*

Many compounds of the metallic oxydes with the earths and alkalies, may be artificially produced; and an infinite variety of them exist in nature; which the chemist has been able to decompose, but not to imitate.

In the systems of mineralogy, the more compounded natural substances are divided into genera; corresponding to the number of the primitive earths, alkaline substances, metals, &c. their classification into species is derived from an accurate examination of their physical and chemical properties.

21. *The more Compounded Vegetable Substances, and Artificial Compounds containing Vegetable Matter; the Fourth Class.*

The organs of plants appear for the most part to be compounded of the oxydes and acids, containing oxygen, hydrogen, and carbon; of water, and the different earths and salts; but we are very little acquainted with the arrangement of these their constituent parts. We can chemically examine vegetable substances only in their dead state; our analyses are usually made by heat; and we are incapable of demonstrating the accuracy of them by synthetical means.

Many important artificial compounds are formed by the union of different vegetable matters, with certain of the alkalies, metallic oxydes, and earths.

The more Compounded Animal Substances, and Artificial Compounds formed from them; the Fifth Class.

The chemistry of animal substances is as yet in its infancy; no accurate views have been obtained with regard to it: an almost infinite variety of composition exists in those organized parts which are most analogous in their structure and uses, and these parts are in a continual state of change.

The substances described in Division 4; Class 4 and 5, appear to exist in the greater number of animal organs; but their arrangements are wholly unknown, and they are combined with very different proportions of water and saline compounds.

The artificial compounds produced by the action of reagents upon animal substances, as yet have been very little investigated.

Of the Applications of the more Compounded Bodies.

The saline compounds, or the neutral salts, are applicable to a variety of purposes. The compounds of the nitric and muriatic acids are the most important in their uses; nitrate of potash is the basis of gunpowder.

Mineral substances, modified by artificial means, are applied to a great number of processes; and most of the earthy and metallic substances, described in the three last divisions, are produced from them.

A few only of the vegetable or animal more compounded substances are employed in the chemical arts in their native states; but their new combinations and decompositions are essential to many important operations.

VI. GENERAL PHENOMENA OF THE CHEMISTRY OF ARTIFICIAL OPERATIONS, AND CONCLUSION.

22. *Generalization of the Facts relating to Artificial Chemistry.*

The general phænomena of the chemical changes produced by artificial methods, may be referred to four different modes of the exertion of attraction. Simple combination, simple decomposition, compound combination, and compound decomposition. And in all cases the law of action is determined by the primary affinities of the elements of the substances experimented upon, and their masses.

Of Crystallization.

In a number of chemical operations, the solid substances produced, assume regular polyhedral forms; and by these forms, their species may in most cases be ascertained.

All known crystallized bodies have, as their nucleus or primitive crystal, one of six regular figures, which are, 1. The parallelopipedon. 2. The tetrahedron. 3. The octahedron, with triangular sides. 4. The hexagonal prism. 5. The dodecahedron, bounded by rhombs. 6. The dodecahedron, bounded by isosceles triangles. The modifications of these forms depend upon diversified and complicated forces of attraction.

Observations on the History and Progress of Experimental Chemistry.

Experimental chemistry is a science of late invention: it has been chiefly formed by the labour and genius of philosophers who have flourished within the last fifty years. It continues to improve, its boundaries are daily extended; and almost every new discovery unfolds new objects for research. The instruments of chemical investigation, though possessed of great power, are still in a state of imperfection; and from the improvement of them, we may expect to obtain new and important arts, and to develop more sublime and comprehensive views of nature.

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